ELECTRO-FARMING:

OR THE APPLICATION OF ELECTRICITY TO AGRICULTURE

by

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INTRODUCTION

by

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PAST-PRESIDENT OF THE INSTITUTION OF ELECTRICAL ENGINEERS.

I, who have watched the development of electrical science for over fifty years, am every day more and more convinced that its great future will be that of supplying electric light and power to rural England; so that by its use, the output of labour on the land will be increased as many-fold as has been the case in our factories and workshops during the last half century.

I fully believe that when this is realised, and that when the supply of electrical energy can be delivered to the farmers at low cost, it will revolutionise English life and will be a step towards the great desideratum, i.e., that of spreading our population, now so crowded into large towns and industrial districts, into the surrounding country and thus re-people the rural England of which we are so fond and so proud.

The author, in this book, has done yeoman's work. After a number of years of practical farming, coupled with careful investigation and experimenting, he has put together facts and figures which will be of great value to everyone now working on, or hoping to work on, this great problem of developing rural England. He has dealt in detail with most of the uses of electricity of which we at the present time have accurate data, and these are ample to inform any intending user of electricity on the farm.

It must not, however, be supposed that the data given in this book, prevents us from considering the many other methods

of utilising electric power, which are now in the trial stage, for we have to look to methods of increasing the crops that we can obtain from our land, by better methods of trenching and aerating the soil, thus to increase the yield of many thousand acres of our arable land, up to that of our market gardens. Again we must not forget that we hope by the use of electric methods to secure the fixation of nitrogen from the air and so supply the chemical manures which we require to make our soil yield its maximum of food value.

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PREFACE.

Electro-Farming is a comparatively new science, consisting as it does in the marriage of two separate arts—electricity and agriculture. Since the Great War, the author has devoted his entire time and attention to an investigation of the combined subjects. It has truly been a most interesting study, so the time and energy expended upon it have been well worth while. The present book is a record of some of the principal experience that has been gained, the more important details of which are set out for the benefit of others, so that they may be able to start where the author left off and so add more quickly to the World's knowledge of the subject and thus sooner benefit everyone.

The author has applied his ideas in practice, on his own six hundred acre farm, where there are now about sixty-seven different applications of electricity—and only two horses are employed. It has been his endeavour throughout, to operate this farm on strictly commercial lines, which include the keeping of proper audited accounts and detailed costings. As this is the day of specialisation, the farm concentrated on the production of high grade milk, high grade pork and high grade eggs—the 200 acres of arable land and the rest of the farm was simply worked to support these three main specialities. Experimental work is carried on quite separately from the farm routine work. As a further interesting experiment, since the data for the operation of a large farm has been obtained, the farm is now being sectionalised and each part put into the hands of a practical working farmer. Opportunities have been taken from time to time to visit almost all European countries to ascertain how and to what extent electricity is employed as

an aid to the work on the farms of other Nations. This has been an interesting experience, to get off the beaten track of the tourist and to see districts where the appearance of a stranger is not an everyday occurrence. It was noteworthy, that the stages of electrification in the various regions seemed to depend largely upon the energy and initiative of the engineer in charge of the local electricity supply undertaking. Hence in almost every locality something different is to be learned.

The author would like to take this opportunity to again thank those Farmers, Engineers, and Manufacturers who have assisted him in facilitating such visits and also supplied him with data and information by correspondence. He would much appreciate any data, comments or suggestions that will further the progress of Electro-Farming. Obviously this work does not profess to be complete the field is already so great that the difficulty lies rather in the decision as to what should be left out.

R. BORLASE MATTHEWS.

GREATER FELCOURT,
EAST GRINSTEAD,
JANUARY,

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CHAPTER I.

ELECTRO-FARMING.

Decimal Class. 621.3F

Electro-farming, or the application of electricity to agriculture, covers a very wide field, the greater portion of which is concerned with electricity as a means of transmitting power rather than the use of electricity itself in some such way as a high tension discharge over growing crops. Though electricity may be applied in place of some other form of prime mover, there is a great deal more in the matter than just coupling up an electric motor by a belt to a farm machine.

The Engineer and the Farmer.

The author's experience in the course of travelling through many countries while making a special investigation of electro-farming is, that but one or two electrical engineers in each country may be said really to understand the subject. The usual attitude is that no special experience is required in applying electricity to agriculture, and this has caused many farm distribution schemes to be unsuccessful. The engineer must acquire a good working knowledge of farm problems.

It must not be forgotten that the supplying of electricity to farms will not be successful unless it is also profitable to the distributor, hence it is essential that both the engineer and the farmer should be directed along right lines by means of suitable educational propaganda. It has been demonstrated over and over again in every industry, that time itself can be short circuited, by a carefully thought out educational campaign. To the farmer must be brought home the great value of the new force ready to his hand. It may be years before he discovers a tithe of its possibilities and it will take a similar period of time for the supply undertaking to obtain a satisfactory load, hence

the obvious need is for the central station itself to first find out the possibilities of electricity on the farm, and then to inform the farmer as to what has been learned, and by mutual co-operation put it into practice.

The fact is often entirely overlooked that agriculture is a very speculative business, and further, the farmer has lost much money in trying out new inventions. As he does not properly understand mechanical contrivances—especially if they are electrical—it is but little wonder that he is a bit chary when electrical schemes are propounded to him.

The Supreme Importance of Agriculture.

Only recently has it been realised that, if properly handled, the total farm and rural demand would be greater than that of the present consumption of all urban districts, including the industries, in any country. Agriculture is the greatest industry of any nation. Indeed, the ultimate wealth of any community is entirely dependent upon its success in agriculture. The individual farmer may be but in a small way of business, but in the aggregate, the farmer counts as a very important factor, for his total numbers are enormous. In every country, more people are employed in agriculture than in any other single industry.

In the past with the rapid industrial and commercial expansion which has taken place, and the concentration of the community in the large cities and towns, the questions of electric supply and distribution have been directed practically entirely to these centres, to the great neglect of the countryside, which has been left far behind in the steady advance of civilisation.

The Future.

However, the times are changing. Apart from the question of farming, there is a tendency now-a-days towards a decentralisation of industry. A return to the rural areas, a return of industries, and a return of the people, in other words, rural reconstruction. It is only natural that the call of " Back to the Land," should be obeyed. Factories, formerly only possible in the towns and cities, are now established in the country districts. Modern civilisation necessitates the supply of electricity

everywhere, in the town and in the country. It is urgent therefore that the energies of supply engineers should be directed towards a study of the special problems of extra high tension transmission and local distribution for the supply of the industries in the countryside.

The Financial Aspect.

A study of this book will show that the farming load is one, the cultivation of which the central station engineer will find well worth while. On the other hand, electricity is so efficient a form of power that no enterprising farmer can afford to neglect a study of the possibilities opened up by it. Whereas it is a mistake to imagine that electricity is the panacea for all the ills from which the agricultural industry suffers, electricity is certainly going to be an important factor in its ultimate salvation.

A System of Classification,.

In the general consideration of the applications of electricity to agriculture in this book, it is proposed to follow the practical order employed in both the International and Dewey systems of decimal classification, as this will greatly facilitate reference which is perhaps of more importance than an attempt to follow what might appear to be a mere logical classification which, however, practice indicates is pretty difficult to attain. The main heads of the classification will be gathered from the list of the Contents of this book.

Those who are familiar with the above mentioned classification systems are of course aware that advantage is taken of decimal sub-division to divide each main group into ten divisions and then if required to sub-divide each of these divisions into ten sub-divisions, and again if necessary further sub-divide these sub-divisions into ten parts, and so on, until the required detail is attained. For most purposes extremely fine detail of minute division is not required. When it is, however, it enables it to be classified or filed in such a manner that it can be found easily and quickly from among all the World's knowledge. To the uninitiated the number of figues required for a fine definition may seem somewhat complicated, and the numbers in themselves

are ungainly and awkward. It must, however, be borne in mind, that these numbers are not really numbers in the ordinary sense but are a numerical shorthand, a little acquaintance with which wonderfully facilitates reference to any particular subject. For example, in accordance with these systems a milk cooler would be classified by the number 637.132.1. The analysis of this numerical shorthand is as follows :—

6	Useful arts
63	,, ,, Agriculture.
637	,, ,, ,, The Dairy.
637.1	,, ,, ,, ,, Milk.
637.13	,, ,, ,, ,, ,, Care of Milk.
637.132	,, ,, ,, ,, ,, ,, Dairy Installations.
637.132.1	,, ,, ,, ,, ,, ,, ,, ,, Cooler.

It will be realised that a decimal classification has a very great advantage, for in time new items may be interpolated between existing ones without disturbing the general practical order in which they were originally arranged. This is not the place or time to enter into a complete description of the system as this is only an explanation of the practical basis upon which this book is arranged, as after all it is going to be used by a reader as a working tool and not for the purposes of evolving a classification.

The Path of the Pioneer.

The first successful step in the path of the pioneer is to get the work in which he is interested recognised by official committees. However ponderous and slow moving a committee may be, it is a means to an end, the end in this case being the spreading of the gospel of Electro-Farming. It is therefore of interest to note briefly the official marks of recognition bestowed by various bodies upon this science. In this country, engineers have led the way. The 1925 report of the Institution of Electrical Engineers' Electricity in Agriculture Committee was the outcome of a lengthy enquiry, and, since that date the same Committee has been responsible for the outlining of schemes of experimental work which this year may see embarked upon.

The British Electrical Development Association has always taken the liveliest interest in the promotion of electro-farming. In 1924 this Association decided, in conjunction with their wonderful domestic and general electric exhibit at Wembley, to also have a separate Electro-Farming exhibit, and this section of the work was arranged and carried out by the author. In June 1924, there was a visit to the farm of the author by the Council of this Association, when a cinematograph film was taken, which has been used very considerably for propaganda work. During the same year, an Electricity in Agriculture Committee was formed, which is still actively carrying on.

A good deal of Electro-Farming literature is circulated by the Association, and the most prominent piece of work embarked on of late (from the Electro-Farming point of view) has been the arrangement of what looks like being an annual institution —a British Electro-Farming Conference. The first of these Conferences was held in 1925, the second in 1926, and in both cases the meeting place has been the Member's Tent of the Royal Agricultural Society of England's Show. (Chester 1925, Reading 1926). At Chester the chair was taken by Lord Bledisloe, whilst at Reading the meeting was presided over by Mr. Llewellyn B. Atkinson. The third Conference was held at Newport, Mon., in 1927. Mr. S. Edwards, Chairman of the Monmouthshire Branch of the National Farmers' Union, was in the chair. Upon all occasions papers were given from the points of view of the farmer and the supply engineer.

The fact that the Royal Agricultural Society of England welcomes such Conferences under its auspices, is a good omen. It is a pity that this Society will not go a little further than it cares to do at present. In 1924, a sub-Committee of the Research Committee was appointed to enquire into the uses of electric power on the farm, but the report was not published. Subsequently a special reporter was appointed, whose report was published. A leading continental electro-farming expert, when shown this report, after perusing same, bluntly expressed it to be twenty years behind the times.

Of late the Council of the National Farmers' Union has been faced by a request from one of its branches to urge the

Government, to make the electrical supply of rural areas a practical proposition with the result that the Council agreed to take such steps as lay in its power. This move was the natural outcome of speculations aroused by the Electricity (Supply) Act. It is to be feared that many hopes have been falsely raised in connection with this Bill. At present, although cheap generation is amply provided for, distribution is not covered. It remains to be seen whether the Central Electricity Board is likely to have the interests of rural areas at heart. Incidentally, passing references made to electro-farming during the passage of the Bill through the House were almost wholly facetious.

Politics and Electro-Farming.

In the arena of politics, electro-farming is recognised to have a vote-catching appeal. In addition to mentioning the subject in speeches, the Conservative and Unionist party have employed an electro-farming film to interest their audiences, in a portable cinema van, with which they have been touring the country. The Liberal Land Policy contained brief references to rural electrification. The matter was gone into in the Agricultural Policy of the Labour Party, and rural electrification is a cause which the party indicates it proposes to support.

The work of a non political body, the Rural Reconstruction Association, is not generally so widely known as it might be. The land policy of this Association has been carefully thought out and in it, rural electrification is urged as of primary importance.

Installation.

In England it has from time to time been heard that the engineer must foot the research bill before the farmer can be expected to take up the extensive use of electric power. In contradiction to that view it is interesting to note that in Bavaria and many other parts of Europe, the cost of developing rural distribution lines was borne by Farmers' Associations.

In Japan there are several thousands of Farmers' Associations, chiefly organised to install machinery for pumping, threshing, hulling, etc. Some of these Associations even have their

own power generating stations, one of which (in the Fukuoka Prefecture) has a generating capacity of 1500 K.W.

The Bibliography of Electro-Farming.

No science can be said to have established its mark on current life until it has developed a press and a literature of its own. Apart from an increasingly large number of pamphlets and papers on electro-farming matters, 1925 witnessed the inauguration of three regular journals. There was the Bulletin of the Committee on the Relation of Electricity to Agriculture (America) the "Landsbygdselektrifiering och Motokultur" (Sweden) and "Electro-Farming" (England) which latter has an extensive home, colonial and foreign circulation, larger in fact, than that of most purely agricultural journals.

In January of the present year appeared "L'Électricité Chez Soi" (France) a monthly journal in which a section is to be regularly devoted to electro-farming.

International Aspects.

Abroad the past year has witnessed, for the second time, a World Power Conference at which the subject of electro-farming was discussed. (The first was in London in 1924). In September, 1926, at Basle a whole Section was devoted to "Electricity in Agriculture" and papers on different aspects of the question were contributed by delegates from Great Britain, France, Germany, Switzerland, Norway, Sweden, Denmark, Japan and the United States.

In the United States much interest is attached to the work of the Committee on the Relation of Electricity to Agriculture, of which Dr. E. A. White is the Chairman, and which links up the experimental work of some nineteen different States. It consists of representatives of farmers' organisations, representatives of large Power Companies and representatives of the Agricultural Department of the State College. Experimental work is being carried out in most cases on full scale lines, and the frequent bulletins issued appear to indicate that volumes of data are being collected. Twenty-three men and three ladies are devoting their entire time to investigational work,

hence progress in that country, though backward so far, may soon be expected to advance very rapidly.

Speakers on varied platforms now-a-days preach the gospel of electro-farming. The subject has, in the past year alone, been brought, in the form of papers, before meetings of the British Association for the Advancement of Science, the Institution of Electrical Engineers, the National Farmers' Union, the Incorporated Municipal Engineers' Association, the Society of Arts, the Harper-Adams Poultry Conference, the British Electro-Farming Conference and the World Power Conference.

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CHAPTER II.

THE POWER STATION AND THE AGRICULTURAL LOAD.

Decimal Class. 621.312.F

Supply engineers usually judge the value of any load offered to them by the consideration of its effect on their station load factor.

The following table gives the load factors common to certain industries, including farms :—

TABLE I.

Class of Industry.	Load Factor.
	per cent.
Woodworking Factory	5
Engineering Works	6
Printing Works	8
Cloth Factory	10.25
Dairy Farm	13
Mixed Farm	15
Arable Farm	31
Poultry Farm	55

It is popularly assumed that the farm load is necessarily a much worse one than any town load, both as regards units consumed per annum and incidence of demand. An inspection of the above table, however, shows that this is far from being the case.

In poultry districts very large numbers of chicks are hatched each year. The incubator capacity of some of the larger farms is equivalent to about 30,000 eggs per hatch. Hatching often proceeds for six months of the year, and indeed it is now being

seriously proposed to hatch every month in the year. Taking the case of a hatchery equipped with electrically heated incubators and brooders and dealing with 15,000 eggs (say 11,000 chicks) weekly during the six months, the units consumed would be approximately 180,000. The load factor during the half-yearly period would be 95 per cent. During the remaining six months, the load factor would be about 23 per cent., giving an average annual load factor of about 60 per cent. The maximum demand (during the winter months) amounting to 45 kW. must be compared with the maximum demand of 200 kW., which a cloth factory would demand if it consumed as many units per annum as a poultry farm of this size. Its importance

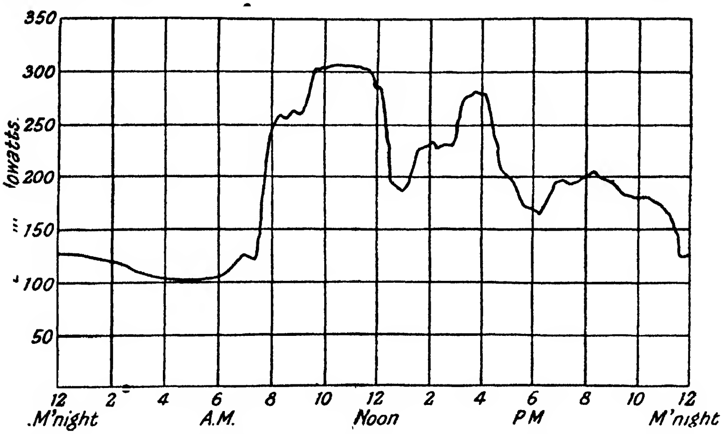

Fig. 1.—Typical load curve for an English rural distribution line

from a supply standpoint can perhaps be better gauged by the fact that its annual consumption is equal to that of an engineering works with 450 horse power of motors installed.

The largest electric hatchery of which the author has details is in California. This hatchery is equipped with 1,200 incubators which are capable of dealing with 604,800 eggs. The current consumption varies from 65,000 to 110,000 units per week, with a maximum demand of over 400 kW. practically continuously during the operating period.

In Scotland there is a poultry farm with a load of 75 kW. on the brooders alone.

The accompanying diagrams, Figs. 1-3, make the position as regards the farm load clearer.

Fig. 1 shows a typical load curve for an English rural distribution line. Fig. 2 shows the load factor over a period of a

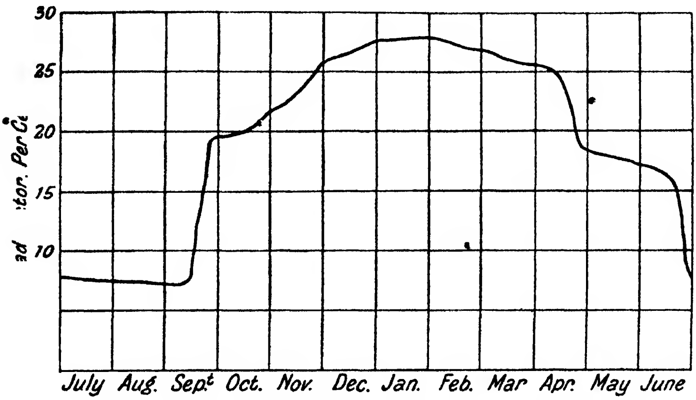

Fig 2.—Load factor of a typical mixed dairy farm.

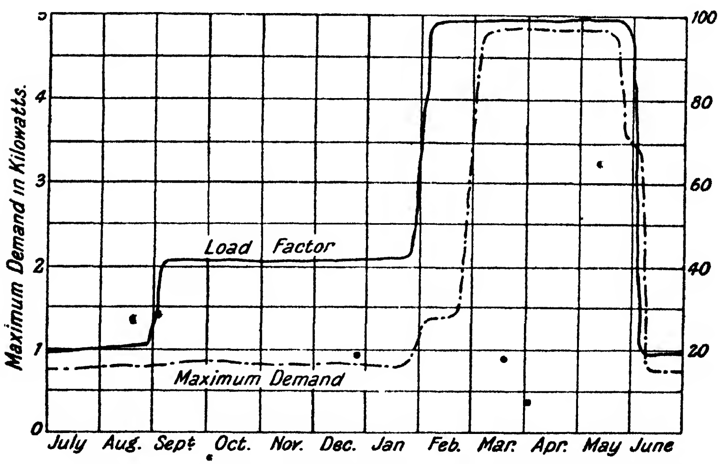

Fig. 3.—Load factor and maximum demand of a typical poultry farm.

year of an average mixed dairy farm. Fig. 3 is of interest as indicating the load factor to be obtained from a specialisde branch of farming, viz., poultry farming.

Any consideration of the applications of electricity to agriculture is complicated by the fact that there are so many forms of the art.

Farming is usually classified into twenty main types, with a very large number of combinations and permutations. The decimal classification given in this book, provides a definite and useful classification that covers the whole field. It must be borne in mind that the nature of farms to be found in any particular district, varies with the average climatic conditions, and ease of transport. This further adds to difficulties in making comparisons. In temperate climates, for all practical purposes, in the consideration of comparative statistics, it will be found to be most practical to divide the farms into six main classes, as follows :—

Arable farming, market gardening, fruit farming, livestock farming, dairy farming, and poultry farming.

An arable farm may be defined as one employed principally in the growing of crops, with only sufficient livestock (say two cows and one hundred head of poultry) to maintain the occupants. The amount of current consumed is fairly constant.

Market Gardens are usually found on the outskirts of cities and towns. The amount of current consumed is not constant. During the Summer months—July, August and September—the load is high. This is owing to irrigation and the use of water for washing purposes. A considerable amount of current is required for cold storage plants. In some countries market gardeners use electric light for trapping moths and other insects.

Fruit farming. The consumption of electricity on fruit farms is fairly constant. In some countries, where a speciality is made of fruit farming, it is found that the current consumption is usually higher during the autumn and winter months, owing to spraying, and the grading of the crop, e.g., apples. From the current consumption point of view, this type of farm is not important.

The Livestock Farm may be described as one which rears pigs, sheep, cattle, horses, etc., in greater numbers than those of an arable farm. The current consumption is uniform except

during a month or two in the summer time, when additional water has to be pumped for the livestock. The electrical equipment usually found on this type of farm is food grinders, food mixers, clippers, etc.

A Dairy Farm may be defined as one upon which there are over nine cows. The current consumption per month is very steady, the extra demand in summer for water pumping is compensated for in winter, by the extra lighting. There are usually about twice as many dairy farms as arable farms. The average annual consumption is about 1,000 units.

Poultry Farming. Where a farm has more than, say, 500 chickens, it can be termed a poultry farm. A typical load factor of a poultry farm is shown in Fig. 3.

A survey was recently made by the Virginia State Committee on the Relation of Electricity to Agriculture with the object of studying the present position of rural electrification in Virginia. The following tables summarise the results of the survey. They are extremely interesting as they are based on the actual consumption in an area where no effort had been made in the direction of propaganda. It is clear that if the farmer could find so many different ways of using electricity, in spite of the fact that no organised attempt had been made to educate him as to its possibilities, then a policy of properly cultivating the farm load would result in enormously increased demand.

It would be a mistake to consider the farm load apart from the power needs of the rural district of which the farms are only a part. There is to-day a distinct tendency towards the decentralisation of industry, and with the prospect of a plentiful supply of power, there is no reason why works, formerly only possible in the towns and cities, should not be better established in the country districts.

Basis for consideration of Rural Load.

In discussing the question of rural supply there is a tendency to consider its feasibility in terms of units consumed per square mile. Naturally, on such a basis the results can never be so attractive as is the case where populous areas are considered. This foundation is really entirely a wrong one upon which to

TABLE II.

TOTAL CONSUMPTION IN UNITS (kWh) ON 414 VIRGINIAN FARMS.

Mth.	105 Dairy Farms	133 Arable Farms	83 Market Gardens	41 Live-stock Farms	38 Poultry Farms	14 Fruit Farms	414 Total
	Units (kWh)	Units (kWh)	Units (kWh)	Units (kWh)	Units (kWh)	Units (kWh)	Units (kWh)
Jan.	7241	5681	2121	2189	576	530	18338
Feb.	8987	5047	1852	1627	666	390	18569
Mar.	8105	4571	2343	1559	559	402	17539
Apr.	8438	4274	2933	1525	612	410	18192
May	8274	4033	4008	1337	575	427	18654
June	9540	3727	6021	1389	562	413	21652
July	9784	3637	6783	1536	621	611	22992
Aug.	9701	3882	5849	2127	660	739	22958
Sept.	11155	4100	6463	2891	831	812	26252
Oct.	8962	4061	3340	2431	793	475	20062
Nov.	7429	4066	2570	1769	648	283	16765
Dec.	5052	4699	2901	1898	698	220	15468
Total	102,668	51,778	47,184	22,298	7,801	5,712	237,441
Average per farm	977.8	389.3	532.3	543.9	205.6	408	573.5

TABLE III.*

TABLE SHOWING NUMBER OF VARIOUS ELECTRIC APPLIANCES USED ON 414 FARMS IN VIRGINIA.

(a) Water.	
Water Pumping systems	132
(b) Farm House.	
Electric cookers	12
Grills	15
Hot plates	2
Toasters	41
Percolators	7
Waffle irons	27
Heaters	16
Fans	37
Sewing machines	15
Washing machines	82
Irons	294
Vacuum cleaners	100
Curling irons	26
Battery chargers	4
(c) Farm Buildings.	
Silo fillers	3
Apple graders	2
Sprayers	1
Wood saws	1
Emery wheels	5
Incubators	2
Brooders	2
Milking machines	22
Refrigerators	19
Bottle washers	5
Separators	28
Churns	13

proceed. It is not the area to be supplied, but the length of lines to supply that area that should be considered. In other words, the only correct basis upon which to compare rural and urban loads is the units (kWh) supplied per mile of distributor. The potential revenue considered on this basis is equally as attractive in rural districts as in towns. The following figures have been worked out for loading per mile of distributor. For comparison, similar figures have been given for English urban districts (usually a much prized load, though not comparable with modern American practice).

TABLE IV.

	Loading per mile of Distributor Units (kWh) per annum.	Annual Revenue.	Price per Unit (kWh)
RURAL.			
Farms over 300 acres.			
Lighting, cooking, heating and barn work	10,500	175	4
Do. plus ploughing	34,500	430	3
Small Farms under 150 acres.			
Lighting, cooking, heating and barn work	22,500	375	4
Do. plus ploughing	48,000	600	3
URBAN.		250	3
100 Consumers per mile	20,000	to	
		333	4

From the above table it will be seen that where rural loads are properly developed, the possible revenue is at least as large and valuable as from the ordinary town load—which is profitably supplied. As a matter of fact, anything over 5,000 units per mile of rural distribution is profitable. It must not be forgotten that in many cases the cost of the distributors and consequently the interest and depreciation to be offset, will be considerably lower in the case of the rural line than is usual where the distributors are supplying city streets. Moreover, in the case of overhead distribution, the expense of increasing the current-carrying capacity will be relatively small, and will

amount only to the cost of cables and insulators plus labour for attaching to the existing poles.

There are already routes where the consumption per mile of 10,000 volt distributor, without ploughing, is equal to, or more than, the urban figure given in Table IV.

Practical experience indicates, at the present stage, that in order to provide a remunerative electricity supply, a quarter to a third of the area must be arable or rich dairy land. The point is not so much whether electric ploughing is to be employed or not—it will probably not be used in many districts for a few years—as the fact that a farmer with a good proportion of arable land needs to treat, in some way, the crops which he produces, or else he has to prepare food for stock. The amount of power necessary for these purposes has a direct relation to the area of land under the plough, and also to the fertility of the soil. In some of the more fertile parts of Europe the consumption of electricity is already 100 units per acre, without taking into account any current actually employed on the land for ploughing or other purposes. Ploughing and cultivation would have consumed an additional 60 units per acre, while treatment and handling of the crops would absorb up to 40 units per acre. Over and above all this, there is a very important load that has not yet been touched, viz., that of haulage, estimated at about 75 units per acre. Thus, under ideal conditions, it is possible to conceive a consumption of 275 units per acre, based upon present practice. As an illustration of what that would mean to this country alone, assuming that its 57 million acres of land were all suitable for agriculture, on the above basis of consumption, the requirements would be about 16,000 million units per annum, whereas the present output of all the central stations in the country, including the output for railway work, is only 7,415 millions. Thus the hypothetical requirements for agriculture would be more than twice those for all other purposes. If the agricultural consumption were only one-twentieth of this, it would be as great a load as that of the power companies on the North-East coast of England, admittedly a very large output (about 800 million units per annum).

These approximations are supported by a statement made by the United States Department of Agriculture (which has recently made a very careful survey of the consumption of all kinds of power used on farms) " . . . agriculture in the United States uses practically as much primary power as all manufacturing and central station plants combined." This seems to be the position in almost any country.

Without ploughing or haulage, a figure of 10 to 30 units per acre may at present be taken as a fair average upon which to base calculations for this country. Ploughing and cultivation would take 45 to 60 units per acre, while threshing would need 24 to 45 units per acre, depending upon the heaviness of the crop. The demand of rural industries usually amounts to 25 to 30 per cent. of the purely agricultural consumption. As more industries are attracted to the country, this proportion increases. An analysis of the electricity supply to 34 rural districts in Germany showed the results set out in Table V., and these could be very considerably improved if the farmers were shown how to make better use of the supply.

TABLE V.

CONSUMPTION OF ELECTRICAL ENERGY IN 34 GERMAN RURAL DISTRICTS (WITHOUT ELECTRIC PLOUGHING).

Class.	Units (kWh) per acre.	Units (kWh) per hectare
Lighting	12.5 to 22.5	30 to 55
Power	27.5 to 42	65 to 100
Totals	40 to 64.5	95 to 155
Average ..	50	125

A district in Italy containing 3,060 hectares (7,560 acres) shows an annual consumption of 129,814 units, corresponding to 17 units per acre (40 units per hectare) per annum. The charge per unit is 0.28 to 0.35 lira ($2\frac{3}{4}$ to $3\frac{1}{4}$ pence), and a guaran-

tee of 900 to 1,000 hours' use of current during the year is required. This is not always attained, with the result that the price per unit is then correspondingly increased. Notwithstanding these conditions the number of consumers is constantly increasing. The average demand is 8 to 10 kW per farm, but each farmer endeavours to arrange his power requirements so as to reduce his maximum demand, which of course, is taken into account when fixing the minimum charge which he will have to pay irrespective of his consumption.

In Friesland the winter load due to threshing machines alone amounts to 500 kW. This gives some idea of the magnitude of the loads that are to be obtained.

In certain districts in France, 125 horse power ploughs are in use, coupled through their own transformers, direct to the main 30,000 volt transmission lines. Such a set works steadily all through the autumn, winter and spring—Sundays and night time included—and hence is a welcome addition to a rural distribution scheme.

As the farming field in most countries is practically untouched as regards a supply of electricity, it affords the central stations an excellent opportunity to put forward the full advantages of electric power. Here it may be remarked that schemes should be submitted to the farmer, that enable him to purchase current on the most favourable terms. As an illustration, a scheme originally devised by the author for a small water-power installation may be mentioned here. Though initiated to avoid the necessity for the purchase of a governor, it is worthy of careful consideration in dealing with farm supply. The basis of this idea is that if the farmer takes a constant supply of electricity (100 per cent. load factor) he will be granted an extremely favourable rate by the Electric Power Supply Authority. Now by means of the multiple-way switching diagram, shown in Fig. 4, the farmer can take a constant supply, and yet obtain the convenience of using that current wherever he wants it, as long as his total demand for current at any point does not exceed the pre-arranged constant amount.

This amount is determined by the current-consuming capacity of the apparatus connected. If all the groups of

appliances on the farm and in the farm-house consume the same amount of current the desired end can be attained.

In the case which is represented by the diagram it is assumed that the demand settled upon is 5 kW., and the requirements are for :—

(a) Driving electric motors of various sizes ;
(b) Cooking ;
(c) Heating of water for the dairy and for the house ;
(d) Heating of rooms.

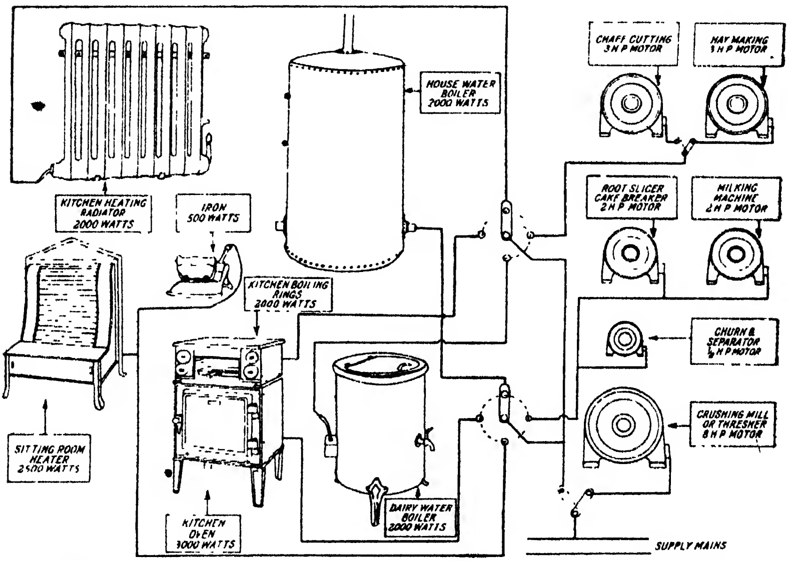

Fig. 4.—Diagram of a scheme for a 100 per cent. farm load factor. (The negative loads are omitted for simplification).

The important loads are, of course, the driving of the motors and cooking ; hence, in practice, whenever either of these is not required, the current is switched on to any of the others that may be desired. In the summer time the radiators would not be used, so the current, when not employed for cooking or motors, would be always on to the water heater.

The arrangement shown is entirely diagrammatic. In practice two-way and multi-way switching would be employed, so that whatever was required could be switched on near that point.

To avoid any confusion between the house and the farm a red light might be arranged over the motor switch, to indicate when the oven was on. A similar red light scheme would also be advantageous to indicate to those in the kitchen that a motor was in use. All the motor switches would be so arranged that when a motor was stopped, its proportion of current was switched on to other apparatus.

Provision for dealing with electric lighting is not incorporated in the diagram, to save complication. The best way to deal with this is to divide it into sections, and by means of multiple-way switches use the current for heating water when not required for lighting. This system has been developed by Mr. E. S. Russell, and is installed in a considerable number of houses in the Shoreditch district of London.

It must be admitted that under such a scheme, the wiring becomes more costly—but it is worth it. Again, troubles in making the correct connections might arise unless the wiring contractor was given a definite plan to work to. These schemes are but the forerunners of the "Change Circuit" methods, which are now becoming well established.

Price of Current.

The farmer can afford to pay a good price for electric service, and does so in those countries where electric power is already available on farms. In the great majority of cases charges for farm supply are settling down to (a) a fixed charge based upon the distributors, (b) a charge for the transformer iron losses, (c) a charge per unit consumed during daylight hours, and (d) an increased charge per unit consumed during evening hours. (Any charge based on connected load is fatal for a farming supply). This compound system works out very well in practice, as the farmers, overlooking the proportion due to the capital charges which they realise they have to pay anyway, find the current cheap to use, since the cost of the unit, without other charges, is really low. This system gives the impression to farmers who do not use electricity, that electricity can be obtained very cheaply elsewhere, as compared with the total rate mentioned as probable for any proposals in their district. This advantage is often put down to the availability

of water power. It is, of course, a mis-conception, for though in certain cases water power is cheaper than steam, all depends upon the cost of development. As an illustration, power produced from steam in the North of England is sold at a lower figure than that produced from the falls of Niagara. In Sweden there are over 52,000 electrically equipped farms where the rate for electricity is higher than in most large English towns. In fact, in the South of Sweden electricity can be produced by coal transported from England as cheaply as by water power for the conditions of farming loads.

Generally speaking, it is of far greater interest to the farmer to know that he can obtain half-an-hour's light from a 10 watt electric lamp for the value of one ordinary wooden match than to be told that the price of electricity is five pence per unit.

Such information will help the farmer to appreciate what electricity can really do for him and is much better than theorising upon the cost per unit.

As a rough average, on the Continent the farmer pays a total of fourpence per unit for electric power, and sevenpence per unit for electric lighting.

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CHAPTER III.

PRIVATE ELECTRIC GENERATING PLANTS.

Decimal Class. 621.312.4

Unfortunately, there is only a fraction of the farmers of many countries in the happy position of being able to obtain a public electric supply. Though there are signs that something will be done in the near future, in the matter of electrifying the rural areas, it would be unwise to count too much on this, as there does not appear to be any immediate prospect of general electrification. The new British Electricity (Supply) Act of 1926, does not cover the matter of distribution at all, only generation. Even if it did, it would take many years to complete the task. Those who are contemplating installing a generating set would be wise however in selecting a voltage similar to that of the nearest supply in anticipation of the extension of the supply mains.

The standard public supply is 230 volts. This is also the pressure of the larger private plants. This voltage or at any rate not less than 100 volts, is to be strongly recommended for any electric generating set that is to be employed for farm work. Many regret to-day that they purchased low voltage plants, of say, 16, 25, 30 or 50 volts, since they find that these voltages are really only suitable for lighting in the immediate neighbourhood of the engine room and cannot conveniently and economically be used for lighting or power at a little distance away.

It is not generally realised that those who happen to have low voltage plants of say 25 volts can purchase more battery cells, making the total number up to say 54. Then the battery will provide the required total voltage of 100 to 110. A change-over switch will have to be provided so that the electric set can charge up the whole battery section by section to correspond

to its voltage. If the new cells are the same size as the old ones, the total capacity of the original 25 volt battery will be quadrupled.

The only objection to purchasing a 100-volt plant is the slightly higher initial cost, but the many advantages to be gained from the higher voltage set amply compensate for the difference in price, also it should not be forgotten that as the big public demand is for electrical apparatus at 100 to 120 volts or 200 to 250 volts, it is easier and cheaper to obtain appliances for use with these pressures.

Water Power.

It is not often realised that 250 cubic feet of water falling at the rate of ten feet a minute will provide sufficient electric power for light, heat and the small motors of an average farm. That is to say, the farmer through whose land a stream flows should take steps to find out what power in terms of electricity the same will provide. The utilization of water for driving a water wheel does not diminish or pollute the stream, although where a dam is constructed, the effect of back-water upon the adjoining land must be carefully considered, so that damage to property may be avoided.

A water wheel in its simplest form is merely a circular fan with curved iron blades revolving in an iron case. The wheel revolves owing to the force of the water driven through the blades and the blades cause a shaft fitted with pulleys to revolve, these latter being connected to the pulley of a dynamo.

There are three kinds of water wheels :—

1. Reaction Turbine (for low heads).
2. Gravity Wheels (Undershot breast, Overshot).
3. Impulse Wheels (Pelton) (for high heads).

The Reaction Turbine is one of the most popular of water wheels and is generally used for medium and low heads and comparatively large quantities of water. It runs at a higher speed than the overshot wheel, occupies much less space and is more efficient. Many different sizes of turbines are stocked by good makers, whereas with overshot wheels, they generally have to be built specially for each installation, which increases their cost.

The Overshot Wheel used to be employed for heads varying from 4 to 60 ft., although it was rather expensive for heads of above 20 ft. As the efficiency is low, it is not a type that is generally installed to-day.

The Impulse Wheel, popularly known as the Pelton wheel, has an efficiency of about 80 per cent. and although it is generally used for heads of water of 100 ft., or over, to an indefinite volume, it is also obtainable for heads as low as 20 ft. It is most suited for use in mountainous districts where the quantity of water is small but the head relatively high.

Careful investigation is needed before installing a water power plant, as the interest on capital expended on constructing dams and the laying of pipes, etc., is often greater than the annual running costs of an internal combustion engine. If construction costs can be kept reasonably low, there is no doubt that water power gives more satisfactory results than any other type of plant, providing there is sufficient water at all seasons of the year to operate the plant. The ideal condition is where the minimum flow is sufficient to supply the maximum demand at the season of low water. It is also necessary to know the maximum flow of water in flood time because the dam and spillway must be capable of dealing with this. The power of the stream depends upon two things, the head or fall which can be secured either by the aid of the dam or naturally, and the quantity of water flowing. The higher the head, the cheaper the capital cost of the installation. Where the flow of water is sufficient to meet the maximum demand at all seasons of the year, a battery can be dispensed with by installing a turbine, which is controlled by a hydraulic pressure governor. Though these special governors are rather expensive, the cost and depreciation is very much lower than that of a battery. A further item to consider is the distance from the available water supply to the place where the current is to be used, as the cost of the transmission lines may be so high, that it becomes cheaper to install an engine driven generator, which can usually be placed near to where the current is needed.

Automatic water power plants are also obtainable. With these plants the dynamo and turbine do not run continuously.

When the charge in the battery falls below a certain value, an electric motor, which opens the sluice gate is brought into operation. In this way the dynamo charges the battery at full load. When the battery is completely charged the set is shut down by the closing of the sluice gate.

Windmills.

While windmills have been employed for many years for the purpose of pumping water, it is only during the past few years that serious attempts have been made to generate electricity in this way, though as far back as 1881 Lord Kelvin, when he was Sir William Thompson, in his Presidential address to the Mathematical and Physical Science Section of the British Association, suggested the idea of employing windmills for the generation of electric power.

While early models simply fitted the generator to an ordinary pumping windmill, modern plants are designed specially for the purpose for which they are to serve.

Probably one of the reasons why windmills have not been more extensively used in this country, is that there has not been any really reliable data for the prospective user to consult. The Institute of Agricultural Engineering of the University of Oxford, recently carried out a series of investigations at Harpenden with a number of modern wind plants manufactured by representative makers. Figs. 5 and 6. The results of their work have now been published, and provide the prospective user with a most valuable and reliable guide.

It is an interesting fact that in the Netherlands, (*i.e.*, a country with every wind advantage) the windmill is rapidly being replaced by the electric motor. During the last few years the number of windmills in use has decreased by about fifty per cent. The usual practice is to install a twenty horse-power electric motor in the base of each windmill. It is found that at the higher pressure of work to-day and the necessity of turning money over quickly, coupled with the higher value of men's time, that work cannot await the vagaries of the wind. Also in wet weather there is rarely any wind, and there seems to be a lot of wet weather.

The essential components of a wind-motor consist of a head-piece, i.e., the part which swings in the wind and carries a wind-wheel, and the necessary support for this head-piece. The generator is mounted either beside the wind-wheel or on the ground. A direct drive is never used, as the speed is always too low. Spur or bevel gearings are often utilized, and on some equipments a belt or chain drive is fitted. The gearing and

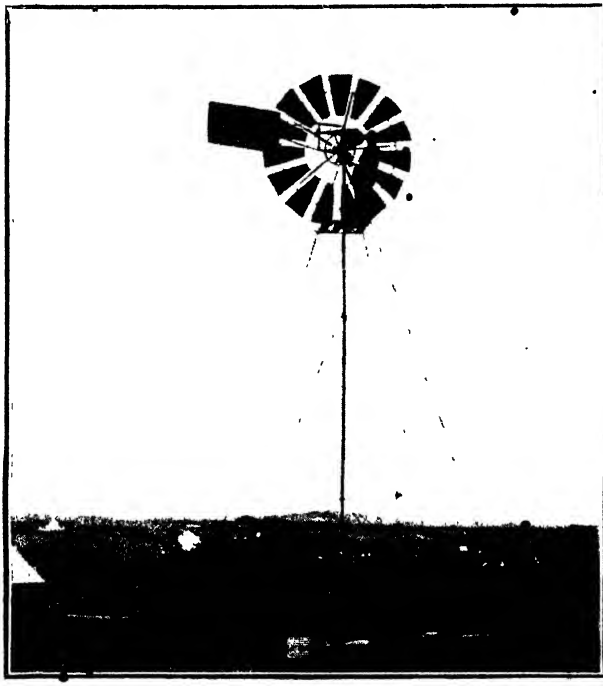
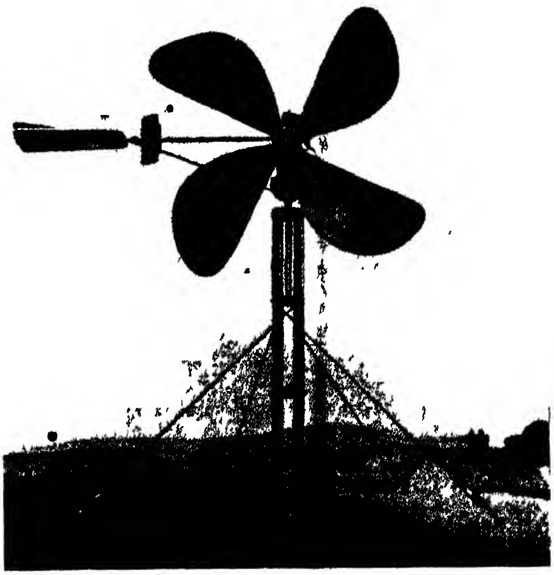


Fig. 5.—The Garty "Apex" Windmill. *Glasgow Electrical Engineering Co., Ltd.*

dynamo is usually protected from the weather by means of hoods and in the best types these are designed in stream-line fashion to give as little obstruction as possible to the wind.

The modern windmill, in nearly all cases, runs with the plane of the wheel practically vertical and normal to the direction of the wind. To enable this to be done a tail or vane, fitted at right angles to the wheel, is attached by means

of springs to the head-piece. When the velocity of the wind increases, the output of the generator is naturally greater, but when the speed of the wind exceeds a certain figure, the power transmitted to the generator will exceed the safe load on the machine, unless some means are adopted to govern the speed of the wheel. The methods adopted vary considerably according to the makes of the windmills. A method that has proved very



The Patent Lighting Co., Ltd.

Fig. 6.—The Ventimotor.

satisfactory, is where a governing-vane, smaller than the tail-vane, is fixed to the side of the wheel and in a plane parallel to it. When the speed of the wind exceeds the safe limit, the tension on the springs, by which the tail-vane is attached, is so adjusted that the pressure on the side-vane is sufficient to overcome their pull and the wheel is turned slightly out of the wind, thus controlling the speed in all winds.

Electricity generated from windmills is not as cheap as some people imagine ; it is certainly not a case of getting something for nothing.

A very large storage battery must be installed to maintain a supply of electricity when there is no wind to operate the dynamo. The battery is also necessary for steadying the power supply during periods when the veloctiy of the wind varies—for contrary to the general idea, wind always comes in gusts and is never steady.

One or two types of windmills have been designed to operate without a main storage battery, but it cannot be said that they have proved practical, because only during periods of high winds can the full capacity of the machine be obtained. This is very unsatisfactory as the load must be suited to the condition of the wind, rather than the supply be forthcoming according to the need of the farmer.

As very much larger batteries are required for use in conjunction with windmills than with other prime movers, the cost of the battery must be taken into consideration when comparing the cost of a wind installation with any other.

The following table gives the results obtained from the investigations carried out by the Institute of Agricultural Engineering of the University of Oxford :—

TABLE VI.

RESULTS OF THE INVESTIGATIONS CARRIED OUT BY THE OXFORD INSTITUTE OF AGRICULTURAL ENGINEERING ON SEVEN WINDMILL GENERATING PLANTS.

Type of Windmill	Air[illegible]lite	Airolite m[illegible] with new wheel	Garty Ape	Garty Ape with new wheel	Garty Ape	Ventu m[illegible]	A[illegible]ro dyn[illegible]	Ag[illegible]	Ventu[illegible]or
Rating of Generator in kW. ..	1.5	1.5	0.4	0.4	0.4	0.25	10	5	0.25
Diam. of wheel in feet	14	12.5	8	8	8	8.5	29.5	22	8.5
Height of structure in feet	60	60	50	50	30	10	32	55	20
Cost in £	193	193	80	80	68.5	95	400	215	95
Approx. cost of battery in £ ..	150	150	50	50	50	25	500	200	25
Gross output per year in Units, (kWh).	1028	1334	456	684	316	326	7640	3580	368
Cost per Unit (kWh) in pence	11.3	8.7	9.5	6.4	12.7	11.6	4.1	4.0	10.3

It will be seen that the medium sized plants stand in a favourable position as compared with the costs of other methods of power production. As the successful operation of a windmill depends upon the choice of a suitable site, too much care cannot be taken to see that nothing interferes with the prevailing winds. The investigators at Harpenden found that the majority of winds are South and South-west.

A small form of wind dynamo has recently appeared on the market which is of interest to farmers. Its primary purpose

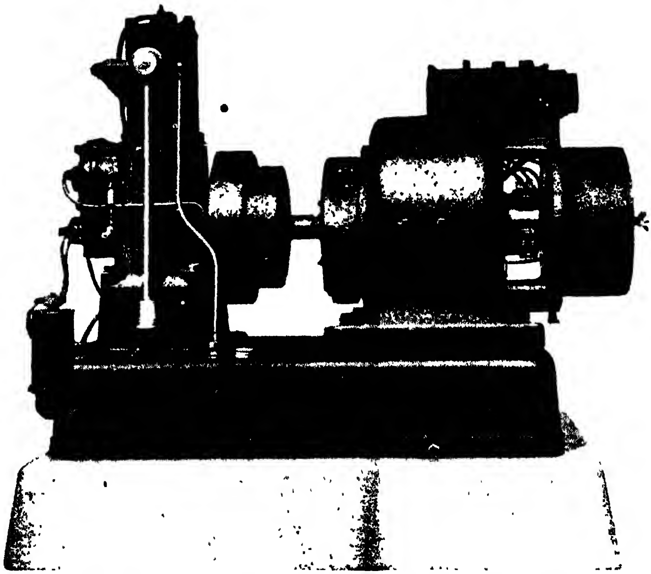


Fig. 7.—A 1 kW. " Austinlite " Automatic Set.
No Switchboard is required with this set.

is to provide a means of charging low-voltage batteries for wireless installations, motor cars, etc. The windmill is mounted on a platform which is fitted with a swivel-head and wind-directing vane and consists of a high-speed dynamo having a capacity of 25 to 30 watts. The weight of the apparatus, which can be mounted on any pole, is 25 lbs.

The above windmills are all fitted with stream lined blades or wings of aerofoil section, i.e., similar to the air-screw or wings of an aeroplane. The efficiency of such a modern wing, is over

double that of the popular multi-bladed La Cour or American windmill.

Internal Combustion Engines.

Where only a small amount of current is required, there is no doubt that the petrol engine is the most suitable. (Fig. 7). Petrol gives little trouble and prolongs the life of the engine. However it is an expensive fuel and should only be used for

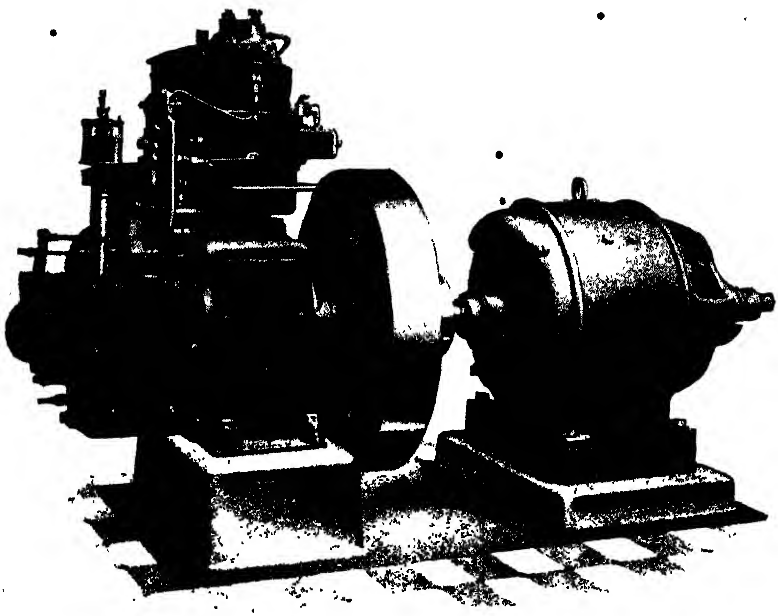


Fig. 8.—A 3½ kW. Heavy-Oil Automatic Austin Set. (When once started the engine fires by compression and no coil, magneto or sparking plug is required).

small sets. While paraffin is much cheaper it has certain disadvantages, for instance, the cost of lubricating oil is increased as some of the paraffin finds its way into the crank chamber and thus deteriorates the lubricating oil. If the plant is to be over eight horse power, the semi-diesel, cold-starting type of engine is probably the most satisfactory, as a cheaper, heavier oil than petrol or paraffin can be used. These engines are of

very simple construction, and are often made without magnetos, sparking plugs, etc. When these engines are carefully overhauled by an experienced engineer every few years, practically no trouble is experienced. (Fig. 8.)

Storage Batteries.

Where electricity is only required for say the lighting of poultry houses or the driving of certain machines, then a battery could be dispensed with. However, if the current is used for one purpose, it is certainly unwise not to take advantage of it for the lighting of the home, because, whatever the source, it would certainly be much cheaper than burning oil lamps. For practically all farm conditions it might be said that it is advisable to have a battery with a generating set, as in this way the engine works at its highest efficiency, for when only a few lights are being used, the battery is storing up the surplus electricity which can be drawn upon when extra lights are required. No engine can be expected to operate without requiring some attention at some time and it is at these times that the advantages of a battery are really fully realised, as they can be used as a reserve to tide over these periods. A further advantage is that the design of the engine driving the dynamo need not be of such a high class type, as any good engine will drive a dynamo for charging a battery, whereas if lighting is done directly off an engine and dynamo, a rather expensive engine is required, which must be fitted with a very sensitive governor. The three principal methods of controlling the charging of a battery are hand control, semi-automatic and fully-automatic. The first method is seldom met with to-day, while the third still has certain drawbacks, in so much as, no matter how automatic a set might be, it still requires a certain amount of attention, and for this reason, what are known as the semi-automatic sets, are perhaps the most popular at the moment. The principle on which these semi-automatic and fully-automatic sets work is, that when the battery requires charging, a two-way switch magnetically connects the dynamo to the battery and disconnects it when it is fully charged.

All batteries are rated by their ampere-hour capacity, i.e., the number of amperes discharged in a given number of hours.

A 100 volt battery with 120 ampere-hour capacity will give 12 amperes for 10 hours discharge at 100 volts ($12 \times 100 = 1200$ watts for ten hours) which will light thirty 40-watt lamps (1200 watts $\div$ 40 watt = 30 40-watt lamps for 10 hours).

There are 1000 watt-hours (or 1000 watts for one hour, or one watt for 1000 hours) in an electrical unit. Hence one unit will light twenty-five 40-watt lamps for one hour ($1000 \div 40 = 25$). Again taking the example of the 120 ampere-hour battery at 100 volts, this means it has a capacity of 12 units (12 amperes $\times$ 100 volts $\times$ 10 hours $\div$ 1000 watt-hours = 12 units).

Table VII. shows the number of 40-watt lamps that can be lighted at the same time for a period of ten hours from batteries of various capacities.

TABLE VII.

Capacity of battery at 10 hrs. rate	25 Volts 14 Cells	50 Volts 27 Cells	100 Volts 54 Cells	220 Volts 120 Cells
Ampere-hours	Number of 40-watt Lamps in use			
60	4	7	15	33
80	5	10	20	44
100	6	12	25	55
120	7	15	30	66
150	9	19	37	83
200	13	25	50	109
240	15	30	60	132

The battery and its surroundings should at all times be kept clean. If this is done a great deal of trouble will be saved in the course of time. The battery should be thoroughly inspected at regular intervals to see that the deposit at the bottom of the cell does not touch the bottom of the plates and also to remove broken or displaced separators or any foreign material that has got between the plates. If this is done the danger of

internal short circuits is minimised and the life of the battery considerably lengthened. Readings of the density of the acid in each cell should also be taken at regular intervals. Special floating densimeters are obtainable for this purpose.

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CHAPTER IV.

AGRICULTURAL ELECTRIC MOTOR DRIVES.

Decimal Class. 621.313F.

TABLE VIII.

Food Preparation for Livestock.

Chaff cutters.
Chaff dust extractors.
Root pulpers, slicers and cutters.
Cattle cake breakers.
Corn crushers, kibblers, rollers, grinders and grist mills.
Disintegrators for ditto.
Corn or maize shellers, huskers and shredders.
Food sifting and mixing machines.
Meat grinders and mincers.

Pumping.

Pumping of water for domestic use and for stock (open tank and pressure systems).
Pumping of liquid manure.
Pumping of sewage.
Whitewashing machines.
Irrigation by means of electrically operated pumps.
(a) spraying.
(b) shallow root crop, and
(c) deep root crop.
Liquid manure distribution by means of electric pumps.

Hoisting.

Portable electric winch.
Hay and crop hoists.
Hay and crop elevators and transporters.

TABLE VIII. (*contd.*)

Hoisting (*contd.*)

Food transporter.

Cart loader.

Driving mechanical conveyors and pneumatic or other elevators for silos and threshing machines.

Grain and chaff elevators.

Sack elevators.

Stable Tools.

Horse and cattle clippers and brush groomers.

Horse and cattle vacuum groomers.

Sheep shearers.

Workshop.

Grindstone (also mower knife grinder).

Workshop for repairs to farm machinery (including grindstone, emery wheel, drilling machine, portable electric drilling machine, lathe, forge blower, electric soldering iron, electric glue-pot, etc.).

Wood choppers or splitters.

Circular saws.

Farm Work.

Artificial manure distribution by electrically operated machines.

Fence post driver.

Stump and root pullers.

Potato digger.

Potato sorter or grader.

Crop Treatment.

Grain and seed graders.

Winnower or fanner mills for cleaning seeds.

Hay balers.

Straw and hay chaffing machines (also in combination with threshing machines).

Hop dryers, shredders and dryers (centrifugal).

Dessiccation of vegetables and fruits by electric fan.

TABLE VIII. (*contd.*)

Crop Treatment (*contd.*)
 Pulping of fruits for supply to jam makers.
 Lucerne or alfalfa mills.
 Flailing machines.
 Malting machinery.
 Clover, pea and bean hullers.
 Seed cleaning and dressing.

Ploughing	See Chapter IX.
Harvesting	,, ,, X.
Handling Crops	,, ,, XI.
Threshing	,, ,, XII.
Electro-Silage	,, ,, XIII.
Electroculture and Light Treatment ..	,, ,, XIV.
Irrigation, Pumping and Liquid Manure distribution	,, ,, XV.
The Poultry Farm	,, ,, XVI.
The Dairy Farm	,, ,, XVII
Applications of Electricity in the Homestead	,, ,, XIX.

Farm Drives.

On the average farm, the machines that are most commonly power driven are hay chaffers, root cutters, grinding and crushing mills, cattle cake breakers and firewood saw benches. Figs. 9-13. These machines are chiefly used during the winter time, and even then for but a few hours daily. Hence, at first thought, the load factor of a farm does not appear to be very attractive. However, if electricity is available, experience shows that it will soon be employed for a variety of other purposes, if only the attention of the farmer is drawn to its possibilities. A very important use, where water is not already laid on, is for driving the water pump for general farm purposes and also for domestic use. Still another service, which may be reckoned among the essentials, is the driving of a liquid-manure pump. For the driving of the milking machines two to three horse power is required. The preparation of food for the livestock is usually carried out in the morning, so that if a threshing machine

and also a hay and straw transporter and elevator are added to the above equipment, there will be a fairly constant load for twelve hours each day during the winter.

At the hay and corn harvest periods, the driving of the barn machinery would be replaced by the operation of an electric

Fig. 9.—A portable electric motor driving a root cleaner and slicer.

fan for curing the hay and sheaves of corn, also for elevating hay and silage crops; in addition a chaffing machine would have to be driven for cutting silage. If a number of sheep were kept, an electric shearing machine should be employed. Fig. 14. In fact, once electric power is available, its use will

extend in many directions as indicated in Table I. After all, the requirements of each farm have to be specially studied, as the form of farming so often differs, as does also the arrangement of the buildings.

Portable Motors.

With a view to the elimination of countershaft drives and also to enable each piece of barn machinery to be placed in the

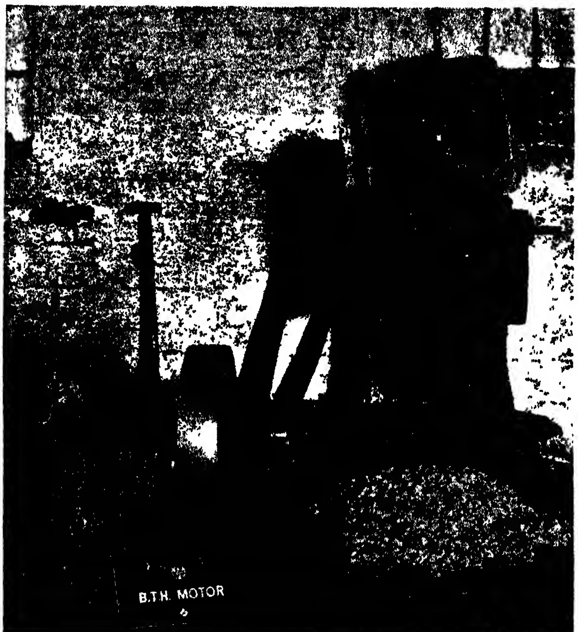

Fig. 10.—A portable electric motor driving a cake breaker.

position where it is most convenient for it to do its work, portable electric motors are having a considerable vogue. Their use certainly reduces the number of motors necessary on a farm and also the capital invested. However, it is a moot point as to whether in the course of the year's use, the value of the time lost in adjusting and fixing them would not pay the interest and depreciation on a direct-connected motor. As a matter

of practice, this is the custom of farmers who have had a number of years experience of electric driving. They find that their machines are not employed to full advantage, unless they can be operated by a twitch of a switch.

Fig. 11—Electrically driven corn crusher.

Portable motors have, however, one great point in their favour, i.e., they enable new drives to be tried and experimented upon in cases of doubt. For work outside the farm buildings, they are often invaluable and are a most useful addition even when the main drives are fixed.

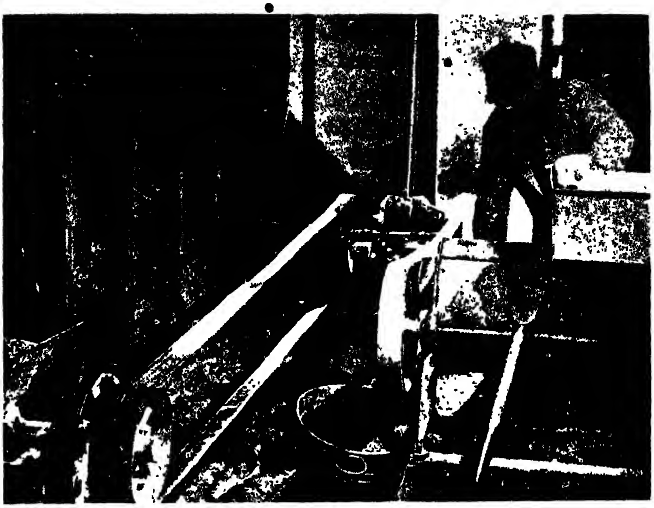

Fig. 12. -Electric motor mounted on truck, driving grinding machine on left and grain cleaning machine on right.

Fig 13.—An electric motor driven hay and straw chaffing machine.

Electric Motor Specification.

Electric motors for use on farms, should preferably be provided with starting switches and fuses (or circuit breakers), which are mounted on the motor frame. The flexible leads

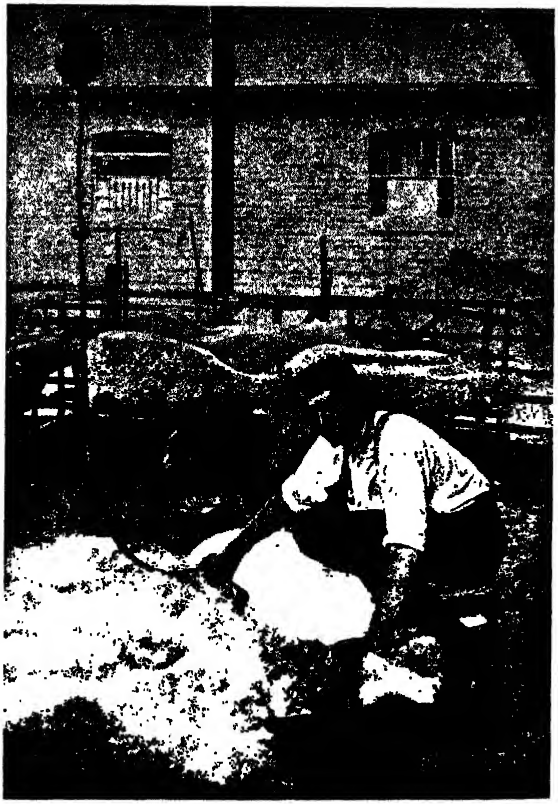

Fig. 14.—Sheep shearing by electricity.

from the source of supply, should form a cable in which an extra earthing wire is included, though in Continental practice this is omitted. A convenient standard length of cable is 40 feet. If a longer length is necessary, a light wooden reel should

Fig. 15.—A portable electric motor, driving a portable circular saw.

Fig. 16.—A portable electric motor, fitted with special plug which permits it to be connected to the nearest power point.

be supplied upon which to coil any excess length not in use. A double width pulley should be fitted on the motor spindle, that is, the type of pulley usually employed for driving on to fast and loose pulleys. The reason for this is so that the alignment of the portable motor may be quickly made, since the setting need not be so exact with a wider pulley as with an ordinary pulley.

If the motor is of the ordinary open type, it should be provided with a drip-proof or a dust protecting cover, either

Fig. 17.—A removal trolley being placed under a portable platform.

of metal or asbestos lined wood. If not protected by such a cover, the motor should be supplied with a shaped tarpaulin cover, to be thrown over it, when not in use. Small motors complete with starters and flexible cable can be obtained ready mounted on handled bars, enabling them to be carried from place to place by a couple of men, like a stretcher ; alternatively, the motors are mounted on timber skid frames or on double or multiple wheeled frames, on which they can be drawn into

convenient positions, being ready for service in their new location as soon as the belt is attached. Figs. 15 and 16. Continental practice favours very substantial, three point suspension, horse drawn enclosed vans, for motors of fifteen to forty horse power.

Platform transporters for Motors.

For smaller motors, the author advocates wood platforms, suitable for use with transporter or lifting trucks, as employed under modern factory conditions. This is a very simple and effective means of mounting so as to make the motor easily transportable, at a minimum cost. This type of platform is made with legs or side supports, so that the transporter or

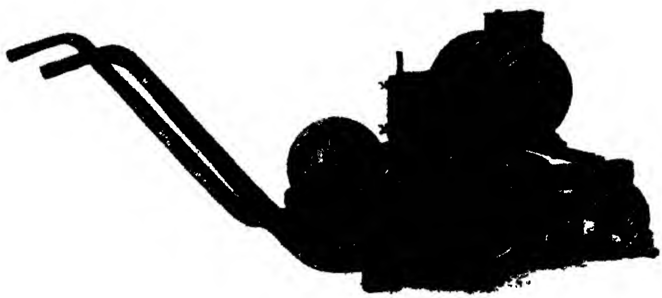

Fig. 18.—Portable motor mounted on light truck.

lifting truck can be pushed underneath it when it is required to move the motor to another place. These trucks are so designed, that by operating the draw-bar handle up and down, the chassis rises, and so lifts the load. When the load is transported to its desired situation, the raised portion of the chassis of the truck is lowered, until the wood platform rests on the ground, when the truck can be removed to do other work. These trucks and platforms, will be found to be very useful for many purposes on a farm, other than for shifting portable motors. As a modification of the above scheme, where it is not considered desirable to acquire a transporter truck, the author has employed a similar platform, but fitted with four

crowbar operated lifting cam-legs. A crowbar is inserted in the hole provided in each leg and they are levered up in turn. With the lighter motors, one end of the platform can be lifted by hand and the legs allowed to fall into a vertical position by gravity. A piano removal trolley is then placed underneath the platform, which is subsequently lowered on to it, by aid of the crowbar or by pushing when it is ready for transport. Fig. 17.

Belt Speed Reduction.

A particular neat and compact form of portable motor is shown in Fig. 18. The outfit consists of a light truck which

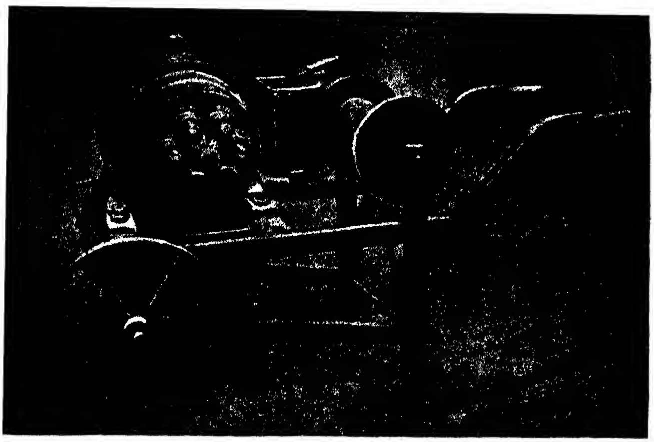

Fig. 19.—Portable motor showing special gearing box for low speeds.

can be wheeled about by one man, and on which is mounted a five horse power, totally enclosed motor having a pulley on one shaft extension of the motor, and driving by means of a Reynolds chain, a countershaft equipped with a double pulley at the one end and a grindstone at the other. The three pulleys give a choice of belt speeds suitable for driving the usual farm machinery. When required to operate a machine it is just wheeled into position and anchored by chocks which are attached to the frame by links and can be swung under the wheels. A stake is also provided which is put through a hole in the foot.

The starter is mounted on the motor and is provided with a no-volt release, so that the machine is protected in the event of the supply failing and being unexpectedly restored.

Geared Motors.

There are a number of small machines on the farm whose power demand is comparatively low, yet when the work is done by manual labour, it is not only heavy, but expensive. Small portable motors are now manufactured, which are designed to operate these machines. The special features of these motors

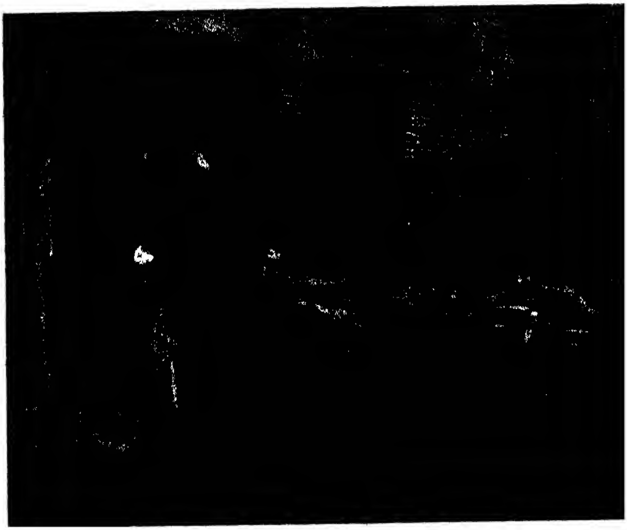

Fig. 20.—Portable motor with tubular shaft driving a corn crusher.

are that they are light, compact, cheap and capable of driving the machine at the crank handle. As the motor speed is of necessity high, special gearing is incorporated to give very low speeds. Fig. 19. Some designs provide for two or more speeds and in some cases the electric motor has become an accessory which is bolted to the side of the gear box. Gear driving spindles, which run at 40, 60, 100 or 200 revolutions per minute respectively project at one end of the box and at the other end, a direct drive of 1,400 revolutions per minute is obtainable. An attempt

has been made to minimise the low power factor of this type of motor by equipping it with a special switch, by means of which the windings of the motor are coupled in four different ways to give various outputs, while at the same time keeping the power factor high. These motors will give from 1 to 5 horse power according to the position of the switch. To avoid the trouble of alignment with different machines, tubular shafts 6 to 7 feet long are provided. Fig. 20. The ends of these shafts are fitted with hooke joints. In this way the geared

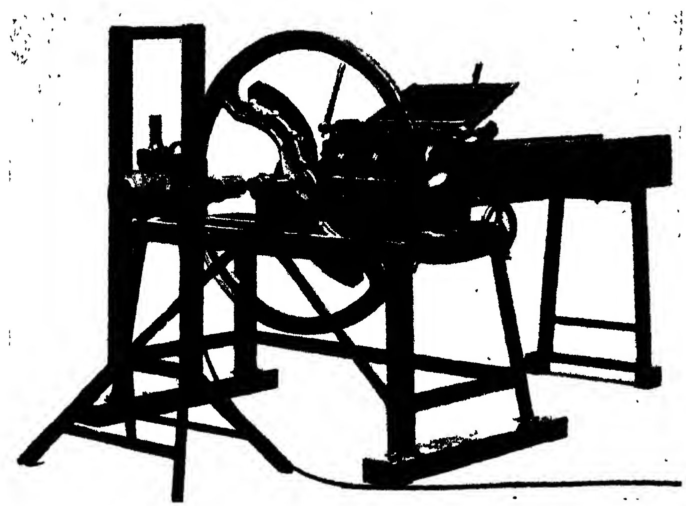

Fig. 21.—Chaff-cutting machine driven by a small portable electric motor

motor can be placed on the floor and from this position will drive a machine whose axle is two or three feet above ground level.

Light Hand Motors.

Another development of the electric motor for driving light farm machinery, is the design of a small, very high speed motor running at about 3,000 revolutions per minute, which can easily be carried with one hand. It has a multiple reduction gear, which brings the speed down to 60 or 70 revo-

lutions per minute. For most purposes it can be employed as a direct drive, but where the starting torque, as compared with the running torque, is high, a friction coupling is interposed. This small motor can also be used for fast running devices, such as polishing mops and emery wheels, and for this purpose, a flexible shaft can be attached to the armature shaft at the rear end of the casing and connected to the device. On the outside of the motor is a starting switch, carrying handles, and an arrangement for fixing the motor to a bed or stand. These motors are supplied in sizes of from one-third horse power to 2½ horse power. The smaller motors are provided with a rotary

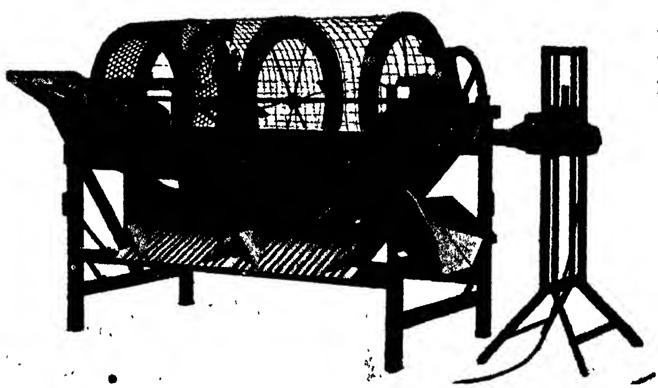

Fig. 22.—Potato sorter driven by a small portable electric motor.

switch for switching on, whereas the larger types have a change-over switch, by means of which the machine can be run in either direction. These motors may either be screwed to a wooden table or iron plate, or mounted on a frame, which enables the motor to be raised or lowered according to whatever machine it may be required to drive. (Figs. 21 and 22).

Power Factor Control.

Farmers starting to use electricity often begin with one or two portable motors, and after a few years adopt the policy of purchasing motors to be permanently installed for individual drives. If suitable machinery is installed, a five horse power

motor is the largest needed on the majority of farms, except in the case of ploughing, while a two horse power motor is useful in addition for general work and one or two fractional horse

Table IX.

SIZE OF MOTORS REQUIRED ON FARMS.

INDIVIDUAL DRIVES.

Drive.	SIZE OF MOTORS.		
	Smallest.	Largest.	Usual Size.
	h.p.	h.p.	h.p.
Book-keeping (Auto-Countancy)	1/30	1/30	1/30
Cart loader	3	5	3
Cattle cake breakers	1/4	2	1
Chaffing machines	2	10	3
Cyclone chaff dust-extractors	1	3	2
Cider mills	2	5	2½
Clippers for sheep and horses	½	1	½
Clover cutters	¼	½	½
Concrete mixers..	2	10	5
Cord wood or firewood saws	3	10	5
Corn maize shellers (single hole) ..	¾	1½	1
Emery wheels	¼	1½	¼
Ensilage cutters..	10	30	15
Fanning mills or winnowers	¼	¼	¼
Feed grinders (large)	10	30	15
Grain elevators	½	5	3
Grain graders	¼	¼	¼
Grindstones	⅛	¼	¼
Groomers (revolving)	1	2	1
Groomers (vacuum)	1	3	2
Hay balers	3	25	7½
Hay hoists	3	15	5
Huskers for Indian corn (maize) ..	10	20	15
Mixing machines	½	5	2
Oat crushers	2	10	5
Ploughs (electric)	12	150	60
Root cutters, slicers and pulpers ..	1	5	2
Saw bench for firewood	3	10	5
Saw mills	10	50	15
Shellers for corn (maize)	10	15	15
Shredders and huskers for maize ..	10	20	15
Winches and hoists	1	10	3
Wood splitters	1	4	2

NOTE.—A very good estimate can be formed of the power necessary to drive a machine by substituting a 1/8 to 2 horse power motor for a man or two men, or replacing a horse or two horses by one 5 horse power motor.

power machines for lighter duties. The farmer who installs a large portable motor for such work as threshing and also uses the motor for a much smaller load, is not an attractive customer

for the power station engineer, as this practice causes the power factor to be very poor. A method of improving this, is to fit a star-delta switch for the stator, the star position being

TABLE X.

APPROXIMATE OUTPUT OF SOME TYPICAL ELECTRIC MOTOR DRIVEN FARM MACHINES.

Machine.	Work done per hour.	Speed of machine pulley.	Size of motor.	Work done per unit (kWh) consumed.
		r.p.m.	h.p.	
Cake breaker	13 cwts.	140	1	1¼ tons.
Chaffing machine.. ..	3 tons	300	10	0.5 tons
Churn for butter (with butter worker) ..	170 lbs	30	2	165 lbs.
Clipper (horse)	1-2 horses	1,300	½	3-4 horses
Clover cutter	50 lbs.	1,800	½	115 lbs.
Corn (maize) sheller ..	26 bushels	280	1	36 bushels
Cream separator	135 gals.	650 bowl 6,000	1½	260 gals.
Ensilage cutter (rye) ..	5.5 tons	300	10	0.66 ton
Feed grinder	40,bushels	1,800	25	3.3 bush.
Grain Elevator	—	—	—	450 bush. raised 19 feet.
Groomer	6-7 horses	1,300	1	9 horses
Harvester and binder ..	2 acres	360 (for knife and binding mechanism).	1½	1.5 acres
Hay curing	—	—	2.5	2 cwts.
Hay transporter	5-6 tons	35	10	0.5 tons
Milking machines ..	90 cows	42 pulsations central pump 390 r.p.m.	3	52 cows
Oat crusher	50 bush.	500	2	22 bush.
Plough (electric)	0.9 acre 12in. furrows average land.	—	60	160 sq. yd
Root cutters	6 tons	150	2	6 tons
Shredders and huskers (maize)	2 tons	—	12	0.91 tons
Thresher	150 bush.	1,200	15	7.7 bush.

marked, say, "light load," and the delta position "heavy load." A practical example of this alteration of connections is illustrated in the following example:—A 25 horse power motor, when used for driving a threshing machine, developed

24 horse power. On 120 days of the year it operated a sawmill taking 13 horse power. When delta-connected the power averaged 11.3 kilowatts, but when star-connected, it was 11 kilowatts, thus saving 0.3 kilowatts. In this particular case, the sawmill was in use 8 hours a day, so that the saving in twelve months was 288 units (kWh). What is even more important is the fact that the power factor was increased from 0.62 to 0.90.

Features of Design.

Electrically operated farm machinery—both the mechanical and electrical portions—should be of such design and construction as rarely to need overhaul, for the farmer who makes a hobby of keeping machinery in repair is apt to neglect his crops and stock. This, in fact, is one reason why machinery is not employed to a greater extent on some farms.

On the Continent, manufacturers are now producing an electric motor which is quite distinct in type from the industrial motor. Since the War, a large percentage (60 to 90 per cent.) of the output of electric motor manufacturers has been of the agricultural type, so much in fact, that these motors are often supplied for industrial work. The general requirements of an agricultural motor are that it must be comparatively cheap, be capable of working in explosive and dusty atmospheres and built so that it can withstand rain and the placing of artificial manure sacks on the top of it. It must also be able to withstand exposure to the weather, to humid atmospheres containing uric-acid and ammonia fumes and receive practically no attention. As regular lubrication cannot be relied upon, ball bearings should be used. The starter should be enclosed in the frame and a simple no-voltage and overload circuit breaker should be provided. The windings should be vacuum impregnated, so as to be moisture proof. The motor must be capable of working in an inverted or vertical position. To avoid special fixed wiring, a plug connection should be used for the cables. Undoubtedly, the most practical motor for farm use is the three-phase squirrel-cage type. For farms of over 300 acres, the author favours three-phase power, 50 cycle, installations on

this account, coupled with the fact that, as soon as a public power supply is available, it is nearly certain to be three-phase, so the farmer who already has a private installation will not have to change his motors.

The squirrel-cage induction motor can be used for practically all the drives encountered in farm work. Having no brushes or collecting devices it requires no attention beyond the lubrication of the bearings. As a rule on a farm the machines to be driven, are started up at no load, so the conditions favour this type of motor. Considerable difficulty is frequently experienced with the installation of a suitable counter-shaft drive, owing to the fact that it has often to be placed in somewhat antiquated buildings. On some of the more up-to-date farms, counter-shafts fitted with ball bearings are employed, and arranged for self-alignment. While the counter-shaft arrangement is a simple and convenient device, the author has discovered that it is extremely difficult to get farm workers to carry out such a simple task as keeping the belts in order. This trouble is aggravated by the fact that the machines are not in constant daily use. Where counter-shaft drives are employed on farms, it would be a good plan to mount the driven machines on slide-rails, like those used for an electric motor, as this would save much belt trouble.

Electric Motors compared with other Motors.

The most complicated form of electric motor, is the type used as a generator for ignition work (more familiarly known as a magneto) on oil tractors and internal combustion engines. If attention to the magneto, were all that is necessary to keep an engine in good humour, oil engines would long ago have displaced manual labour ; but the electrical part of their equipment is the simplest detail and yet one upon which, relatively, the greatest stress is placed. Some measure of the reliability of the electric motor in hard service may be formed by considering the proportion of troubles due to magneto defects to those caused by derangements in the other and more sensitive organs which go to form the oil engine's internal economy. The complete induction motor contains only about half the

parts required in the oil engine's magneto. In all machinery, reliability and upkeep are largely functions of the number of parts. Hence the outstanding merit of the electric motor.

The electric motor is very cheap in first cost, as might be expected from the fewness of its parts. It does not require periodical expensive overhauls; it never has to be decarbonised, and it has no valves to grind. To start it, all that is necessary is to close the switch, a movement taking but a fraction of a second and requiring no real effort. It starts with certainty, there is no element of chance, and no need for priming, swinging, adjusting carburettors and the like. In starting, or trying to start the oil engine, the only certainty is that under the most inconvenient circumstances it will give the maximum trouble, as in very cold weather. Again the life of the electric motor, because of its simple and robust construction is long—twenty or thirty years under average conditions. Consequently five per cent. or seven and a half per cent. is ample depreciation to allow. It is not necessary to sell it off at half-price after two years, in order to escape the greater loss or heavy repairs, as has been recommended for oil tractors. But there is one other point upon which the electric motor surpasses all other motive agents, and that is, its instant and sufficient response to all demands upon its driving power. It has a high efficiency which is maintained throughout its life, and varies from 80 to 95 per cent., according to size. It only takes sufficient current to meet the moment's demand; it is consequently much more efficient in varying loads than any oil engine can be, no matter how well governed and controlled. Moreover, the overload capacity is very high. An economical 10 horse power oil engine will not give 20 horse power for even short periods, but a 10 horse power electric motor will give 20 horse power or more, the specified overload capacity being usually 100 per cent. momentarily and 25 per cent. for half an hour. The steady, even turning moment of the electric motor gives the most uniform results, and imposes the minimum strain on the machinery being driven. There must inevitably be far greater strain where the motive power is produced by a series of violent explosions. Indeed, one has only to compare the tractive effort

curve obtained in ploughing with an oil tractor, with that obtained under similar conditions with an electric plough to appreciate this fact.

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CHAPTER V.

SYSTEMS OF OVERHEAD TRANSMISSION.

Decimal Class. 621.319.22

The problem of providing the rural areas with electricity at a price which the farmer and rural dwellers generally can afford to pay, is directly effected by the design of the transmission and distribution system. A large percentage of the price paid for electricity is accounted for by transmission costs and a considerable proportion of the costs are independent of the carrying capacity of the lines. For this reason, the first cost of the lines should not be made unnecessarily high by insisting on an absolute continuous supply in rural areas and also on very small voltage variations. Again, many of the restrictions in Great Britain surrounding the erection of overhead lines are more stringent than those which apply to other public utility services, for instance, the guarding which has to be erected at road and railway crossings is often a sheer waste of money, while the preferential treatment given to the Post Office telephone authorities, owing to their long established position, is a severe handicap to many supply authorities. As a result of a very close examination of the whole question, the author believes that the best method of getting rural lines erected up and down the country, would be by the State arranging some form of long term loans at low rates of interest, since the lines cannot be remunerative for a number of years, unless a very intensive educational campaign is put into force. The State should certainly help in this matter, as it can afford to take a longer and broader view than that possible for private enterprise. As a safeguard against this outlay, the authorities receiving the loan should be compelled to undertake an intensive educational publicity campaign in the uses of electricity, and also to commence repaying the loan as soon as revenue permits.

It should be noted that this suggestion is rather one of facilitating finance and not a Nationalisation question.

Way Leaves.

This matter is a very serious one in the consideration of most distribution systems, and is one that must eventually react on the consumer. In most countries legislation is required to ensure that one section of the community is not penalised on account of the selfish interest of the few—who generally, in any case, reap the advantage of enhanced value of their property.

Until the passing of the Electricity Acts of 1919 and 1922 no compulsory powers existed in this country for acquiring wayleaves, so that it was possible for one selfish landowner to hold up an overhead transmission scheme. This state of affairs was no doubt responsible for the backward state of Great Britain, as compared with other countries in the matter of overhead lines. It is not generally appreciated that a rental of one shilling for a ten inch diameter pole, represents £1,000 per acre; hence those landowners who are obtaining 2/-, 4/- and 8/- per double pole (and there are many to-day) are doing pretty well—to put the matter mildly—for the land would not be worth more than £25 per acre for agricultural purposes. In France, they would get twopence halfpenny and in Germany—nothing, per pole. It is difficult to get more than one shilling per pole, even in towns, from the Post Office Telephone Department. This is a case where experience over a long period assists considerably. It does not seem to occur to anyone that the presence of an electricity supply line adds to the value of the land, so the owner ought really to pay a premium to the enterprising erectors of the electric installation.

Layout of Extra High Tension Lines.

The layout of the line only differs from the usual practice in that additional tappings have to be provided en route. Normally, an extra high tension transmission line merely serves to link up the super-power stations in two or more important cities or towns, tapping through sub-stations. Under conditions of rural distribution these sub-stations will be at more frequent

intervals and probably of the open-air type (and thus cheaper). It has long been customary to duplicate extra high tension lines, and advantage may be taken of this fact in new layouts destined to provide for any intervening rural demand. Actually it will often be found advisable to utilize two (or even three) distinct routes at some considerable distance apart. One route might be the most direct between the towns. The second (and third if required) should go through the centres of gravity of the anticipated rural demand. In other words, what is normally

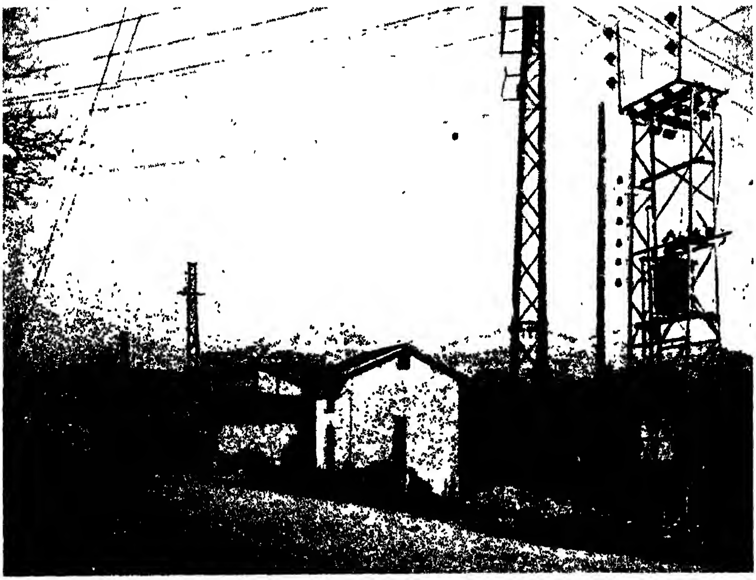

Fig. 23.—Outdoor transformer equipment in French village.

an auxiliary service for the city will become the main supply for the intervening area. At the same time, it is available to render assistance to that city in case of emergency.

Distribution System.

The layout is affected by the low tension voltage required. In the initial days of rural supply in order to reduce line construction costs, it will undoubtedly be the practice to work with a greater voltage-drop during the day-time than would

be permissible for city work. On the Continent, low-tension supply seems to be settling down to 380 volts, three-phase, fifty cycles for power, with 220 volts between one phase and neutral for lighting; whilst in Great Britain, favour is given to 400 volts, three phase, fifty cycles, for power, and 230 volts between any one of the phases and neutral for lighting.

Fig. 24.—Pole mounted transformer, as used on the Continent.

To maintain the above-mentioned voltages, the countryside has to be set out in circular adjoining areas of approximately three miles (5 km.) diameter, each supplied from a 10,000 volt sub-distribution system. At present a 25 to 50 kVA

transformer is usually sufficient for each of these sub-stations, but the transformer capacities will have to be increased later on. Figs. 23-25 show different types of outdoor sub-station equipment in use.

In most countries there is an average of $1\frac{1}{2}$ farms and 2 other consumers per mile (1.6 km.) of low tension distributor.

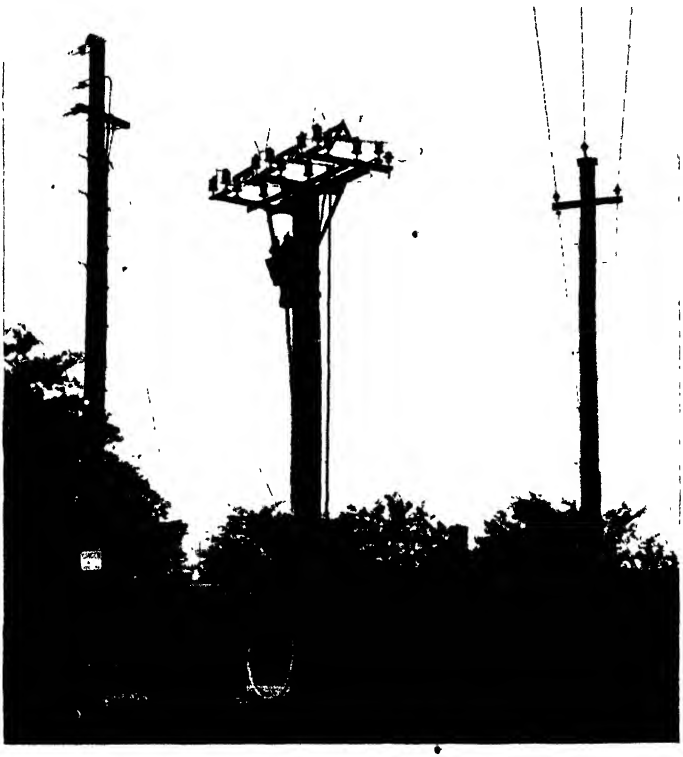

Fig. 25.—Three-phase outdoor sub-station equipped with 6,600/400 volt, 4 wire transformer.

Each 10,000 volt transformer station will supply about 22 farms and 30 to 40 other consumers, including motors totalling up to 300 horse power. Though the load factor per motor is low, that per farm (the more important matter) is high, based on its maximum demand. It averages at present 35 per cent.

giving a consumption of 90,000 units per annum, i.e., 43,000 units per route mile of 10,000 volt distributor.

At the present time, in Great Britain, three-phase overhead lines cost about £500 to £800 per mile; cables would be about double the cost, including laying. The author has put up

Fig. 26.—British rural distribution line, erected by farmers.

similar overhead lines for £200 per mile on private land in this country. In Sweden this work has been done for £100 per mile (the copper in the wires alone accounts for about £50). Figs. 26 and 27 show satisfactory rural lines, erected at a minimum of cost, by British farmers,

While three-phase distribution is the present accepted practice, the advantage of single-phase distribution must not be overlooked. Mr. A. H. Seabrook has quoted £425 as a practical possibility for a single-phase cable, including laying. Or, with less severe restrictions than those at present, he considers it possible to do the work for about £350 per mile.

Undoubtedly much can be done to reduce the cost of laying cables. For instance, there are mechanical trench diggers, already in use on farms, which could well be applied to the

Fig. 27.—Close-up of tree attachment on British farm line.

work. In Canada, caterpillar tractors, hauling deep-cutting ploughs have been employed for cutting the cable trenches.

The Hydro-Electric Commission of Ontario use a standard farm plough and a road scraper. By this means a trench about 18 to 24 inches deep is made near the roadside. The ground is first of all broken with the plough and afterwards the road scraper excavates the trench to the required depth. The filling up is also done by the scraper. At the Rugby Wireless Station,

the earth wires were laid by a special plough, on which the cable reel was mounted.

An example of Extra High Tension distribution.

Assume two super-power stations, "G" and "C," situated fifty miles (80 km.) apart (see Fig. 28) and connected by a 110,000 volt line. If the district was arable there would be an area of supply of about 2,000 square miles ($1\frac{1}{4}$ million hectares). On the basis of estimates made for city conditions, it would seem almost hopeless to think of attempting to supply such an area.

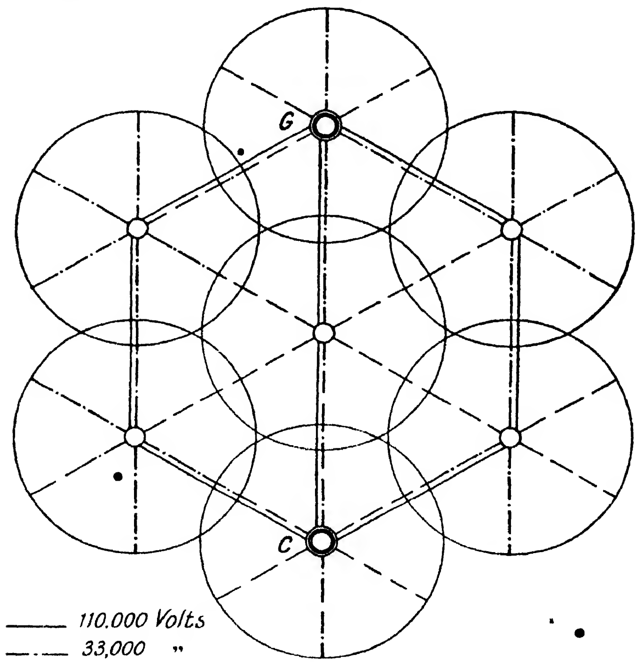

Fig. 28.—An example of extra-high-tension rural distribution between two generating stations. "G" and "C" 50 miles (80 km) apart. The sides of the triangles represent distances of 25 miles (40 km.).

However, if the work is carried out on the lines suggested, basing the distribution on the run of the main roads, it will be found that an annual consumption of 96 million units (kWh) can be supplied by increasing the length of extra high tension line from fifty miles (80 km.) to 200 miles (320 km.). In addi-

tion, there would have to be provided five open-air sub-stations and 375 miles (600 km.) of 33,000 volt sub-transmission lines; and 500 miles (800 km.) of 10,000 volt feeders to the local low-tension sub-stations.

For the scheme set out in Fig. 28, one extra high tension line would go by the shortest route between the cities and two others would also be provided. Of these, one would run parallel

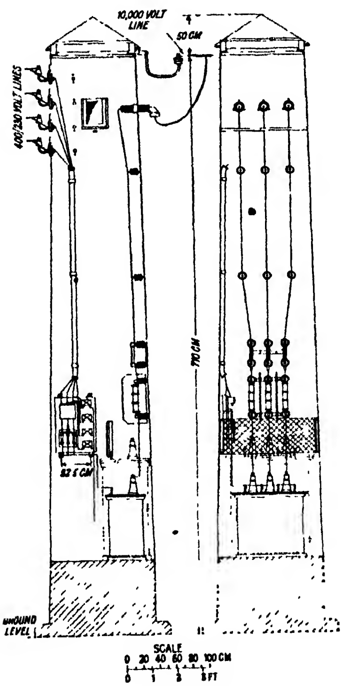

Fig. 29.—A Sheet Steel and Angle Iron Transformer Tower.

on one side at an average distance of say 15 miles (24 km.) and the other a similar distance away on the other side. Thus the five 110,000/33,000 volt sub-stations may be situated at the centres of gravity of the local demands. In practice, the theoretical diagram, would of course, require considerable modification, though the routes suggested for the three extra high tension lines will be found to be characteristic. On approach-

ing the towns, the density of the population and the demand for an electricity supply will increase. Also the distribution of the arable land will not be uniform. This may necessitate a modification of the position of the sub-stations.

It is assumed that the low-tension distribution network (380/220 or 400/230 volts) will be supplied by the local communities. Hence the power supply undertaking would have to consider only the costs up to and including the 10,000 volt sub-stations.

Such a layout only requires one mile of extra high tension 110,000 volt line per 30 square miles (19,200 acres) of land

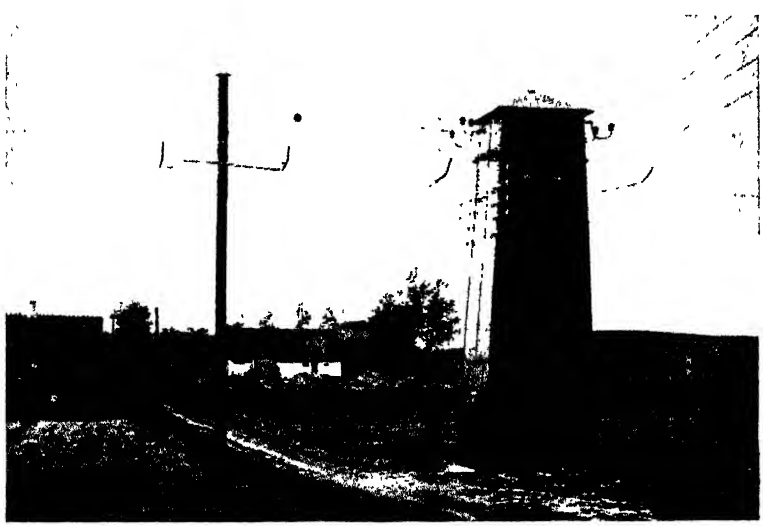

Fig. 30.—Standard Danish 10,000/380 volts Transformer Tower.

(or 1 km. of line per 5,000 hectares), plus a mile of 33,000 volt line per 8 square miles (5,120 acres) of country (or 1 km. of line per 1,030 hectares), plus a mile of 10,000 volt line per 6 square miles (3,840 acres) of ground (or 1 km. of line per 1,000 hectare). Ample provision of 33,000 volt lines is suggested, with a view to the supply of the ploughing and threshing loads. Though the layout is hypothetical, it is based upon actual practice.

It is assumed that the economic range of a 10,000 volt line over a distance of 12 miles (19 km.) is 250 to 650 kVA.

Also that 33,000 volts is an economic voltage for transmissions of 25 miles (40 km.) for quantities of power in excess of 800 kVA.

Details that reduce the cost of overhead lines.

The rural line is similar in costs and construction to the lines required for any other purpose. The matter that requires careful watching is to so design the line, that most of the construction work on the poles, insulators, etc., can be done in the factory and not on the roadside, where labour is so much more

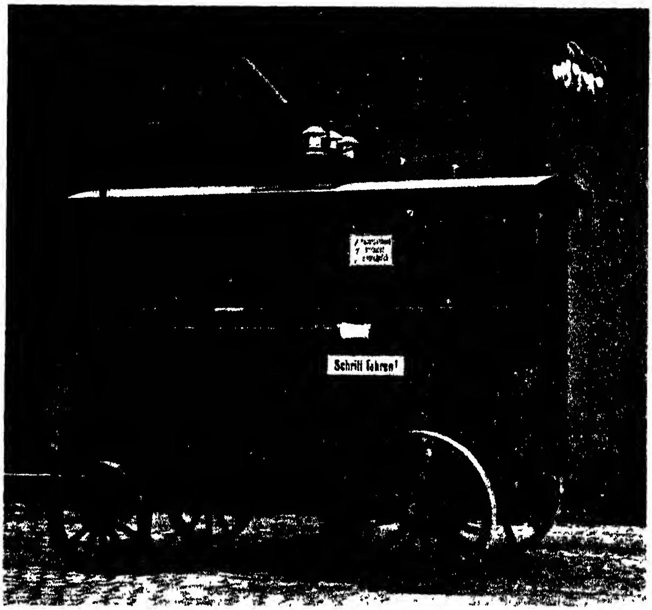

Fig. 31.—Transformer Wagon.

costly. Further, poles of a circular or polyhedral cross-section are to be preferred, since much time is saved if the poles have not to be aligned to match the lie of the conductors. Insulators and their cross-arms should be so designed that they can be clamped on the pole tops without any special drilling or similar work.

The high cost of tapping of the extra high tension lines at intermediate points is perhaps the greatest difficulty. It is receiving considerable attention at the moment. Undoubtedly

the best plan is to provide a sub-transmission line at, say, 33,000 volts, connected at both ends to the extra high tension lines, giving in effect a ring main. From this, 10,000 volt feeders can be supplied for the 50 kVA sub-stations at 3-mile (5 km.) intervals along the rural routes. One advantage of this 33,000 volt sub-transmission is that wood or ferro-concrete poles of a simple character can be employed. Further, it reduces the tapping points from the extra high tension lines themselves to

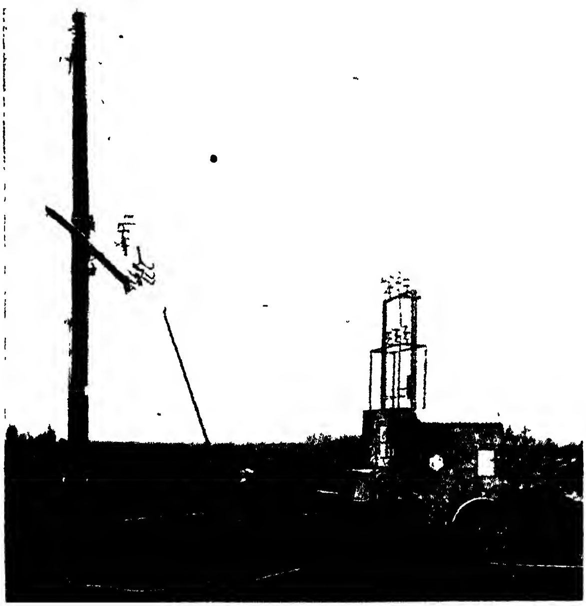

Fig. 32.—Tapping high tension lines. This equipment is used on lines up to 25,000 volts.

a minimum. Very often it is advisable to employ intermediate distribution lines at 1,500 or 3,000 volts.

Maintenance work is much cheaper if the rural sub-station transformers are mounted at the level of a lorry platform (see Fig. 29). Incidentally this illustration shows a very effective form of portable combined tower and transformer station as used in Denmark. It is constructed of galvanised angle iron and flat sheets. Fig. 30 shows the general external appearance.

Temporary Connections.

Heavy loads which move from farm to farm or field as the work is finished are probably better connected to the 33,000 or 10,000 volt lines than to the low-pressure distribution system. The switches, protective gear, meters, etc., would of course, be contained in portable transformer wagons, as is the present practice. (Figs. 31 and 32).

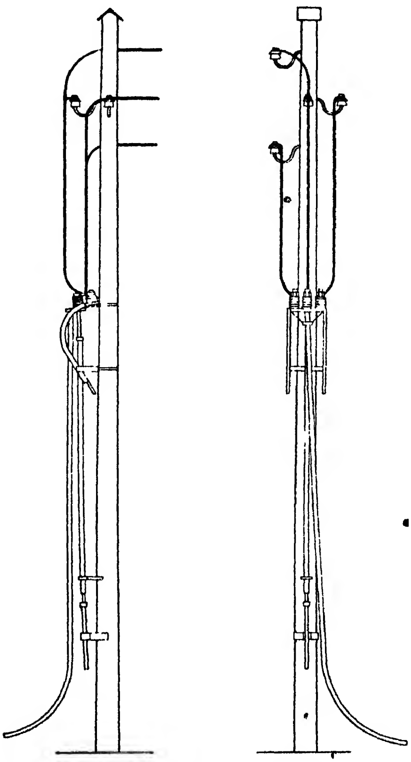

Fig.33.—Working diagram of a 3,300 volt A.S.E.A. Pole Contact for Farm Portable Transformers.

On several parts of the Continent it is permissible to connect these temporary loads by hooks on to 33,000 volt lines. In theory this hardly seems a good method, but the plant is always in charge of a skilled man and in practice the method apparently works well. It has the advantage that any convenient point

on the high tension line can be tapped. However it is probably wiser to provide, as is done in other districts, extra insulators and poles for temporary tappings.

Excellent foolproof temporary connections are now available for 1,500 to 3,000 volts and also 10,000 volts. These can easily be used by the more intelligent farm hands (Fig. 33). Their use means a considerable saving in transformer iron-losses, the transformers being cut out of circuit when not required.

On the farm itself the current is best taken through a meter and main switch (protected either by fuses or automatic features) to an overhead main surrounding the buildings, and forming in fact a ring main round them. Current can then be taken off at the points most convenient with the minimum of internal wiring. As so many farm buildings are of a considerable age, it is imperative to keep all main distributors well outside them, if at all practicable.

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CHAPTER VI.

ELECTRO-FARMING IN OTHER COUNTRIES.

Decimal Class. 630 : 621.3 (40-99)

Germany is one of the most advanced countries in the World in the application of electricity to agriculture. According to the report of the German delegate at the recent World Power Conference at Basle more than 90 per cent. of the farmers, whose farms are in an electrified area, use electricity and during 1925 consumed about 1,030 million units (kWh). During the threshing period, for instance, the maximum load is about 400,000 kilowatts. The total annual consumption per head of population in Germany is 180 units (kWh), while the figure for those in agriculture is as high as 50 units (kWh). There can be no question but that the co-operative idea has done a great deal to bring about this state of affairs in rural Germany. These Co-operative Societies purchase electric energy in bulk and distribute it to their members. In 1901 there was but one rural co-operative society in Germany, but during the following years, owing to the excellent work which the pioneers of this movement carried out, their growth was phenomenal. In 1909 there were 82 societies, in 1911, 300, whereas to-day this figure has more than doubled. Before the War the Government aided these societies by giving cheaper credit than that usually given to similar organizations, but this was stopped during the War and has not yet been resumed, however, it is expected that in the near future some form of Government help will be given. The high tension lines are nearly all owned by the Supply Companies. The low tension lines, however, are almost entirely financed by the Co-operative Societies, who also pay the transformer charges.

Electric ploughing is on a sound commercial basis in certain districts in Germany. Perhaps the reason for this is that steam

ploughing had been carried on, on rather an extensive scale, for a number of years and it is not a difficult matter to demonstrate the great advantages of substituting electric motors for large steam traction engines. The motor load is by far the heaviest in Germany and domestic heaters, potato boilers and silage plants appear to be of far less importance. It is strange to find that in spite of the many applications to be found on German farms, the electric milking machine appears to play a very small part. German agricultural engineers are responsible for a number of very novel applications. A tipping tank for the preparation of cattle fodder during the night is certainly one of these. German engineers estimate that the annual demand would be increased by a 1000 million kilowatt hours if the fodder for only a quarter of the pigs in Germany were electrically prepared in this way. Another novel application is the hot water steeper for seeds, which is due to Doctor Tamm, this equipment is only in the initial stages of development as yet.

France. The French Government has given considerable aid in extending electric power to the rural districts. The main reason for this, is, no doubt, the diminishing supply of labour and a desire to improve conditions in the rural areas so as to attract a better class of labour back to the land. Also it is the countryside which produces the healthiest recruits for the army. If some such step is not taken, it is clear that there is a serious risk of the French agricultural industry declining in importance and prosperity. During the past 25 years there has been a steady drift of the rural population to the cities.

The State has given assistance in the form of grants to rural associations and farmers, and also long period loans at a maximum interest of 3 per cent. In 1923, 600 million francs was voted by Parliament for this purpose and departmental and local authorities are also assisting by granting loans or covering working deficits. Lectures are being given in schools and in villages explaining the practical value of electricity for farm work.

A great deal of attention is being paid to electric ploughing. The most popular equipment at present is the modified double rope haulage system. A very unusual type of small electric

plough is to be seen in some of the French vineyards. The design is most ingenious, for on the front a guide is provided which, when it comes into contact with any vine stems, diverts the plough-share, thus avoiding damage to the roots.

One of the most important applications of electricity in Central France is the use of electric driven pumps for irrigation purposes, and it is of interest to note that the value of the land in certain districts has been increased from nothing up to 30,000 to 40,000 francs per hectare by irrigation work.

The French agriculturists have also carried out a considerable amount of electro-culture work over a period of many years, Tests have been made with atmospheric electricity, static electricity, low voltage, high voltage and high frequency currents. According to recent reports, the tests with high frequency currents appear to have given the best result.

Italy. Thirty years ago, the subject of electro-farming received a good deal of attention and a number of experiments were then carried out, but only during the past twelve to fifteen years has any serious attempt been made to educate the farmer concerning the possibilities of electricity. The entire Valley of the Po is probably the most advanced area in the whole of Italy. Practically the whole of the farmers in this area have their electrical installations. Drainage and irrigation work are the most important tasks to which the electric motor is adapted, though in a number of cases large threshing machines are driven by electric power. Electric current is also used for many other minor operations such as rice drying, forage pressing, cheese working, chaff cutting, olive pressing, etc. Italy, like many other Continental countries, has found that, though electric power may be available, the important question is, how to form the most effective organization to bring the producer and power consumer together. The general solution arrived at, in the interests of economy, is that it is essential for a number of consumers to get together and form a co-operative society for the purpose of purchasing collectively both power and equipment. There are a number of these societies in existence in Italy to-day. Without doubt the most interesting of these is the Societa Co-operative Italiana Agricoltori Meccanica Elettricisti, which

is operating in the Roman Campagna. In 1914, Ing. Alessandro d'Ascani, who had done a considerable amount of pioneer work previous to this time, proposed to the Municipal Electricity Undertaking of Rome that it should construct a special distribution line of ten kilometres in length, which would be used for demonstration purposes, and at the same time provide the farmers in the particular district with a supply of power. The first attempt proved a failure, but in 1915 Ing. d'Ascani built lines at his own expense, the Municipal Supply Undertaking providing him with the power. His enterprise grew rapidly and has now become a very strong co-operative society. The society owns over 150 kilometres of high tension lines, 60 kilometres of low tension lines, and over 60 transformer stations. Beside owning and operating the transmission lines and the equipment, it also owns small tracts of land which are utilized for demonstration purposes. Another co-operative society, known as Anonima per l'Elettro-Agricoltura, was organised in 1920 to take over a number of experimental plants, which had been installed by a group who were anxious to investigate the possibilities of electricity in agriculture. This Company has a very large capital and has erected many miles of transmission lines. Further, it owns a great deal of valuable equipment. In this way it is able to offer the farmer all the advantages obtainable from the use of electric current without asking him to go to the expense of a large capital outlay on equipment. The Company rents its equipment for ploughing, harrowing, pumping, threshing, etc. It owns sixteen electric ploughing outfits and during the year 1923 17,544 acres (7100 hectares) were ploughed for various customers.

The Government, with a view to increasing the food supply of the country, have taken a hand in encouraging the farmer to utilise electricity. In 1919 a decree was issued which provided for the granting of special subsidies for agricultural transmission lines. The Government also contributes a certain percentage towards the cost of construction of certain new power stations.

Russia. Seldom is anything heard of the position of Electro-farming in Russia. However, it should be pointed out that, thanks to Lenin, not only are there more electric ploughs at

work in Russia to-day than in any other country in the World, but the largest electric threshing machines are also to be found there. The largest of these threshing machines require about 150 horse power to operate them. One of Lenin's great ambitions was to see the whole of rural Russia electrified. He realised that his country could not hold her place in the world under whatever form of government she might be, unless she had the mechanical equipment for developing the natural resources of the country. Lenin, however, was no copyist; he believed in the wisdom of leading rather than following. After consulting with experts in the various branches of the science concerned, he decided upon a policy of electrifying many of the rural areas, and a special Commission was appointed to study and deal with the applications of electricity to agriculture.

The importance which has been attached to electrification by the Russian Communists can be gauged from the remarks recently made by Zinoveiff at a Soviet Conference, when he stated, that the importance of electrification as the technical basis for Socialism in Russia was so great that without it a return to Capitalism in Russia was inevitable. There can be no doubt that the nation-wide development of electric service and the use of modern electric equipment in farms and factories will be a very potent agency in bringing Russia out of her social and industrial chaos.

Sweden. The position of Sweden as regards electricity and agriculture was very clearly stated by Doctor Ekström in his recent paper before the Institution of Electrical Engineers.* It might be remarked that Doctor Ekström has been engaged in rural electrification work for the past twenty years and is the owner of a 500 acre all-electric farm. One of the most important points mentioned by Doctor Ekström was, that rural electrification is being carried out in Sweden to-day on a fairly large scale, because it is a paying proposition. Swedish engineers admit that large sums of money have been spent in the past on a number of rural electrification schemes, from which no adequate return was received, yet as Doctor Ekström remarked, they were simply paying for their experience.

* "Twenty Years' Practice in Rural Electrification." By Alfred Ekström, D.Sc., Ahlby Farm, Fittja, Sweden.

While electric ploughing is not carried out on a commercial basis in Sweden, yet one of the most practical forms of electric tractor ploughs is constructed in the country.

The water power of the country has been developed by the Royal Board of Water Falls and the South Swedish Power Co.; both undertakings have taken an active part in the electrification of Central and Southern Sweden respectively. The capital required for the construction of the rural distribution lines in the area covered by the South Swedish Power Company is arranged for by Co-operative Societies and consumers in the district, who arrange for loans to be made to the Company from local Savings Banks on very favourable terms. The raising of money is the only function of these societies, as the Company carries out all the construction work and is responsible for upkeep and management. A similar procedure is carried out by rural customers in the area supplied by the Royal Board of Water Falls, but in the case of the Board, the sole right to build the local distribution lines and the management of the supply is handed over to the Co-operative Societies. One of the chief uses of electric power is for irrigation, though the majority of farmers using power driven machinery, either large or small, are taking advantage of electric power. Considerable interest has also been taken in the preparation of silage and the drying of grain by electricity.

A recent estimate, by the rural electrification expert to the Swedish Department of Agriculture, showed that 3,700,000 acres of arable land in Sweden had been electrified. This is about 40 per cent. of the total arable land of the country and represents over 52,000 farmers.

The Netherlands. The Netherlands is commonly looked upon as the land of windmills and canals, while the existence of her intensive farming is not often noticed. Though the consumption of electricity on the farms is not great, very determined efforts are now being made to supply all the rural areas with electricity, particularly as the electric pumping of water is of such great importance. Farm practice differs somewhat to that usually found in other countries. For instance, rarely are any large scale dairy operations carried on at the farm, as all this work

is concentrated at the creameries, many of which are electrically operated. The load required by the creameries is one that is eagerly sought after by the central station authorities. The following table shows the desirable features of this load, for it will be noticed, the summer load is heavier than the winter load. This, of course, is due to the fact that deliveries of milk are only made to the creameries once a day during the winter months. It will also be seen that the loads fall off before dusk and even the larger deliveries in the summer months are dealt with during daylight hours, i.e., at a time when the central station needs it.

TABLE XI.

Units (kWh) per month.		Maximum Load.	
		Evening.	Day.
January	1444	2.44 kW	
February	1351	2.88 ,,	
March	1448		19.04 kW
April	2840		28.18 ,,
May	4443		26.80 ,,
June	5607		28.94 ,,
July	5868		28.18 ,,
August	5548		20.10 ,,
September	4746		27.87 ,,
October	1885		17.82 ,,
November	1557	2.13 ,,	
December	1431	2.44 ,,	
Total	38,168		

Threshing and straw pressing is usually carried out by Co-operative Societies or large contractors who use 40 horse power portable motors for this purpose. Electrically operated hay and straw elevators are to be found in nearly all the larger barns (rarely is hay and straw stacked out of doors in this country). In fact, the open-sided, roofed structure, known as

a "Dutch Barn" in England, is unknown there, though a small rising and falling stack cover is sometimes used. The remarkable thing about Denmark and Holland, is that in such flat countries, with so many more days of wind than other countries, the electric motor is slowly but surely displacing the windmills on which so much capital has been expended. For many centuries these windmills have provided the power needed for drainage, etc., but it appears certain that when electricity is available throughout the whole country the electric motor will take its place, and the windmill will be seen no more, except as an ornamental relic of the past.

The author has had the privilege of visiting a number of electrified areas in the Netherlands and in practically all rural areas, he found that the farmer did not consider 3d. to 4d. per unit (kWh) too high a price for the convenience of electric service. On the other hand, the central station engineers whom he met, appeared to be of the opinion that the use of electricity in agriculture was, from their point of view, a valuable development, as they found it a comparatively simple matter to keep the farm motors off the peak load of the central station The sizes of electric motors found on the farms are in general from one to five horse power, while the windmill housings are usually equipped with 20 horse power electric motors. Great efforts are being made to provide all the farms with a supply of electric power and it is estimated that an electric service is at present available to farmers in over 60 per cent. of the agricultural areas. In the Haarlem Polder district, 100 per cent. of the farms have a supply.

Switzerland. While it is true that the current consumption in Germany is higher per hectare than in any other country in the World, yet in Switzerland the consumption per head of the agricultural population is equal to that of Germany, viz., 50 units (kWh). There are in Switzerland over 360 hydro-electric power stations producing over 3,000 million units (kWh) per annum. The part which electricity plays in the life of the Swiss people can be gauged by the fact that only 2 per cent. of the population are without a supply, the consumption per head of population being 450 units (kWh). There is no doubt that

Switzerland leads all other countries in the diversity of application of electricity to agriculture and it is only in those countries where grain cultivation predominates that the total consumption exceeds that of this country. Strange to relate, it has not been possible to induce the Swiss farmer to adopt electrical milking machines to any great extent. The reason given by many for this, is that the farmer is still sceptical about the effect of the machine on the cows. A great deal of use is made of electricity in the preparation of cider and in the preservation of fodder and fruit and particularly in the dessiccation of fruit.

Japan. A few years ago Japan found herself in such a position that it was essential to develop some form of power for cultivating the land in order to provide sufficient food for the ever-growing population, which was increasing at the rate of about 650,000 per year. A solution of the problem was looked for in two directions. Firstly it was essential to find a means of increasing the area of land under cultivation and the only possible way of doing this was by reclaiming large tracts of desert land, and secondly the production on the land already cultivated would have to be increased. Electric motors have been introduced for pumping and irrigating the reclaimed areas. Japan was also faced with a similar problem to that of the majority of all countries, i.e., a shortage of agricultural workers, owing to the drift to the towns during and after the War. Co-operative Guilds, Land Improvements and Irrigation Associations have been formed in different districts, and these associations generate electricity, purchase machinery, and erect and equip pumping stations for the common use of their members. For instance, one association owns a power station which has a generating capacity of 1,800 horse power. Electric power is now generally used for threshing, hulling and polishing rice.

Electricity is being used on an extensive scale for silk culture which is an important industry with Japanese farmers. The principal uses are, operating refrigerating machines in which the silk-worm eggs are stored; electric heat for hatching the silk-worm eggs; electric heating of the silk-worm rooms in the Spring and electric ventilation during the Summer months. It is claimed that when silk-worm eggs are hatched in electric

incubators the silk-worms grow much quicker and the cocoons are more productive. Another interesting application, which is finding favour with the Japanese farmers, is the use of electric light for killing moths in the rice field. Before the introduction of electric light for this purpose, paraffin lamps had been used, but it was found that the number of moths caught was proportional to the intensity of the light, thus electric light is replacing the oil lamps, wherever the farmer has a supply of current. Electric fans are occasionally used for drying mulberry leaves after the rain, as the silk worms are liable to become ill after feeding on wet mulberry leaves.

Electricity is also used in the production of tea, chiefly for heating, steaming, washing and drying, and it is claimed that the quality of the tea is improved owing to the absence of gases, which were always present under the old-fashioned methods of charcoal drying.

Canada. The Province of Ontario, which is the most extensively electrified Province in the country, might be taken to show the progress that is being made in the question of electro-farming in Canada, though unfortunately the matter has been treated rather as a political than a practical one. The Hydro Electric Power Commission of Ontario serves about 11,000 rural customers in Ontario and covers an area of over 1,400 miles. While the Commission sells all current at wholesale rates to the cities and towns, it has been found that the rendering of a direct service to rural customers, is the most economic and satisfactory method. During the year 1911 legislation was enacted, with the object of giving a supply of electricity to these rural customers. It was attempted largely by means of extending the transmission lines of the municipality and supplying the rural customers at rates and charges similar to those in the town or city. This method however was found very unsatisfactory owing to the injustice to those consumers who were situated at some distance from the town. New legislation was introduced in 1921, by which authority was given to the Power Commission to serve rural customers direct. Under this arrangement districts were grouped together and current was supplied at a standard rate to those within the district.

At the present time there are about a hundred of these rural districts formed. In 1921 further legislation was passed with the object of bringing electric service within the reach of all rural dwellers. The Government, under this Act, gave a bonus of 50 per cent. of the cost of certain types of rural distribution lines, and in 1924 went one step further and passed a measure whereby they now pay 50 per cent. of the cost of construction of all rural lines.

Charges for power are made up of two parts, a service charge, and an energy charge. The service charge constitutes the greater part of the cost and includes operating, maintenance and fixed charges on the lines and equipment and averages about sixteen shillings (four dollars) per month for farm installations though, of course, this charge varies with the districts and with the class of service. The power charge is divided into two parts. There is a charge varying from 4d. to 1½d. per unit (kWh) for the first fourteen hours use per month, and for all other remaining uses, a maximum charge of 1d. per unit (kWh). Before a rural service is commenced, intensive propaganda is conducted among the prospective customers. Many meetings are held to explain the advantages of using electricity; the cinematograph is made use of to show farm appliances driven by electric power, and field demonstrations are often given in the area.

About one-third of the rural lines in Ontario are three-phase, and about two-thirds single-phase. Generally speaking, 400 volts with a neutral earth is used as a standard. The joint use of poles with the telephone companies is still practised, though a considerable amount of trouble is experienced in the event of an accident, as the power wires are placed above the telephone wires. Underground cables are substituted where trouble is experienced in obtaining way leaves, or when running lines through congested areas, as these have been found cheaper under these special conditions. Those in close touch with farmers in this Province state that a rural service has had an appreciable effect on the development of agriculture. A cheap and abundant supply of electricity has made farm life brighter and far more attractive. In nearly all districts the

rural load has grown rapidly. This is fairly well demonstrated in 65 of the districts where the service charge has decreased from 5 to 40 per cent. In 36 of the districts in the Niagara area, the load increased from 0.5 to 512 per cent., an average increase of 49.1 per cent. during 1924.[4]

The United States of America. Statistics relating to the power available on farms in the United States have been published recently by the United States Department of Agriculture. There are, at the present time, approximately 16,000,000,000 horse power hours utilized annually. Animal power furnishes about 61 per cent , tractors 16 per cent., motor trucks slightly less than 4 per cent., stationary engines 12½ per cent., windmills slightly over 1 per cent., and electric power 5½ per cent.

As long ago as 1900, electricity was to a certain extent being applied to agriculture in California and five years ago it was stated that there were no less than 35,000 electric motors installed on Californian farms.

It was in 1922 that America as a nation started to face the problem of applying electricity to agriculture, and during this year a National Committee on the Relation of Electricity to Agriculture was formed. Its members were drawn from the American Farm Bureau Federation, the American Society of Agricultural Engineers, the National Electric Light Association, and the Federal Departments of Agriculture, Commerce and Interior. The object of this Committee was to encourage and assist the various States in the organization of Committees for the study and solution of their particular problems of farm electrification.

Experimental work has since been carried on, and in January of this year a joint report of the progress in the following twenty states was issued :—

Alabama	Iowa	New Hampshire	South Carolina
California	Kansas	New York	South Dakota
Idaho	Michigan	Ohio	Virginia
Illinois	Minnesota	Oklahoma	Washington
Indiana	Nebraska	Oregon	Wisconsin

The practice of these Committees has been to approach farmers along the lines which were being laid down and to invite their co-operation, so that data could be the more easily collected. In most of the States experimental lines of an average length of six miles have been constructed. Figures from Alabama serve to show how well the idea of electricity has been received once the lines were installed. A two years' report of progress in this State shows an increase in mileage of rural lines of over 300, accompanied by an increase in rural customers of from 240 to 3,600.

Poultry farming experiments have been carried out in twelve different States. Experiments are being conducted in the State of Oregon for the purpose of determining how much a farmer can afford to invest in equipment for lighting the poultry houses without the capital charge being greater than the gain justifies. Results in the Washington State, indicate that profit in the poultry business there, depends upon the keeping of large flocks and experiments are proceeding to determine the largest commercial flock one man can take care of. The prominence of the day old chick hatchery business in the States, makes the work of the Indiana Experimental Station with incubators of 6, 12 and 15 thousand egg capacities, important. In New Hampshire, Ultra-violet ray experimental work is being directed towards the curing of leg weakness in chicks.

The chief experimental work on dairy farms, for the past year, has not been so largely directed towards tests of the equipment as towards the making of records showing operation costs, energy consumption, etc., of milkers, refrigerators, sterilisers, separators, etc. Other branches of work which are being investigated include clipping and grooming of animals, dehydration of fruits, grinding, fertilizer mixing, fruit spraying and grading, hay baling and hoisting, irrigation, seed germination and domestic applications.

It is noticeable that the experimental work in America has been undertaken with a praise-worthy thoroughness, however, some time is being lost as the same ground is being covered that has been previously explored on this side, but probably the varying conditions make this wise.

American Power Companies are fully alive to the possibilities of the rural load as is evinced by the literature that they have distributed in their effort to secure it.

New Zealand. At least 35 per cent. of the farmers of New Zealand have an electrical supply available. Considerable use is made of water power both for public and private generating plants.

Although electric motors are installed to drive threshing machines, chaff cutters, food grinding machines, washing machines, silos, etc., by far and away the larger number of farmers who use electricity are employing it in the dairy. There is also a considerable load derived from dairy products factories. It is therefore, not surprising that the various Power Boards have special tariffs for their dairy farmers. The rates charged by the Danevirke Electric Power Board are typical of what prevails in the country. The rates for electric motor driven milking machines are £5 per year per horse power of connected load plus 2½d. to 1½d. per unit (kWh). This means that for milking alone electric power works out at about ten shillings per cow per year, but against this must be set the fact that one man and a boy can attend to the milking of from forty to sixty head of cattle.

Australia. Following investigations in October 1923, the Victoria State Electricity Commission inaugurated what is known as the Yallourn Scheme serving the Tyers river district near Traralgon. This scheme was developed in the interests of the rural load, and by the beginning of 1926 ninety per cent. of the farmers to whom the supply was available had taken advantage of the same.

The State Electricity scheme is being put into operation and already transmission lines have been erected, or are in process of being erected, into the Western district and into Eastern Gippsland, north to Albury, Corowa, Yarrawonga and Echuca.

Electro-farming is not so far advanced in Australia as in New Zealand, but its advance will obviously follow the same lines. In fact, to date it is generally used in connection with the dairy industry, though many farmers have purchased small portable motors for corn crushing, chaff cutting and wood sawing.

In order to reduce costs, many of the farmers supply much of the labour required for erecting service lines, and the actual cost, in these cases, works out at £33 per consumer. To ensure that a satisfactory revenue will be forthcoming from the lines when erected, each farmer guarantees a minimum annual payment of ten pounds.

Tasmania. Extensive hydro-electric developments have taken place in Tasmania under the auspices of the Government; 90,000 horse power has already been developed, and a further 500,000 horse power is awaiting development. The transmission lines extend well into the rural areas, and six months ago no less than thirty small towns and villages had been connected up, whilst many more were under consideration.

The publicity campaign conducted by the Hydro Electric Department of the Government of Tasmania, in agricultural areas, is already being felt and there is little doubt that the majority of the farms in the areas already developed will soon be electrified.

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CHAPTER VII.

RURAL INDUSTRIES.

Decimal Class. 630.1E

TABLE XII.

LIST OF INDUSTRIES.

From Arable Land Products.

Alcohol Making.
Beer Brewing.
Cider Making.
Collecting of Wild Products, Herbs, Ferns, Primroses, Blackberries, Mushrooms, Holly, Christmas Trees, Mistletoe, Blue Butterflies (for ornaments), etc.
Drying of Herbs.
Drying of Hops.
Drying of Spent Cider Apple Refuse for Cattle Food.
Drying of Spent Hops for Litter.
Drying of Spent Sugar Beet Refuse, etc., for Cattle Food.
Fruit Preserving and Drying.
Jam Making.
Olive Oil.
Pickle Making.
Straw envelope Making (for Bottles).
Straw Rope Making.
Sugar (Beet) Manufacture.
Sugar Cane Crushing.
Vegetable Preserving and Drying.
Wine Making.

Art and Craft Work.

Artistic Ornaments.
Chevening.

TABLE XII. (*contd.*)

LIST OF INDUSTRIES (*contd.*)

Art and Craft Work (*contd.*)

Dressmaking and Millinery.
Embroidery.
Knitting.
Knitting of Elastic Stockings and Silk Surgical Goods.
Lace Making.
Net Making.
Pottery Work.
Rug and Mat Making (Coir and Wool).
Rush Mat Making.
Rush Straw Plaiting.
Saddlery.
Sewing of Clothes (for Town Factories).
Sewing of Gloves (for Town Factories).
Shoemaking.
Soft Toy Making.
Weaving of Patterns and Experimental Work.
Weaving and Spinning.

Contract Work.

Concrete Mixing.
Contract Ploughing for other Farmers.
Contract Stump Pulling for other Farmers.
Contract Threshing for other Farmers.
Haulage Work.
Road Rolling.
Road Scarifying.
Stone Breaking.

From Live Stock Products.

Chicken Jelly Making.
Collection of Feathers for Sale.
Day Old Chick Hatcheries.
Egg Preserving.
Honey and Bees'-wax Making.
Rabbit Keeping for Fur and Wool.

TABLE XII. (*contd.*)

LIST OF INDUSTRIES (*contd.*)

Metal Working.

Blacksmiths' Work.
Electric Motor Parts Manufacture.
Electric Motor Parts Winding.
Electric Welding.
Engineering Work.
Farm Machinery Manufacture.
Farm Machinery Repairs.
Motor Car Manufacture.
Motor Car Repairs.
Tin Smithing.
Watch and Clock Making.
Wireless Apparatus Manufacture.

From Woodlands Products.

Barrel Hoops, making of
Briar Pipes, making of
Brooms and Besoms, making of
Charcoal Burning.
Chip Baskets, making of
Clogs, making of
Compressed Compo.
Creosoting poles for telephone and electric lines.
Fire lighters.
Firewood.
Hop poles, making of
Hurdles and Gates, making of
Logs for Firewood.
Osier Baskets, making of
Paling and Fences, making of
Peat Fuel preparation.
Planing of Timber.
Saddle-trees, making of
Sawing of Timber.
Seasoning of Timber.

TABLE XII. (*contd.*)

LIST OF INDUSTRIES (*contd.*)

From Woodlands Products (*contd.*)

Walking Sticks, making of
Wooden Rakes, making of
Wooden Spoons and Forks, making of

Wood Working.

Boxes for Tin Plate and other goods.
Cabinet and Furniture Making.
Carpentry and Wheel-wrighting.
Gate Making.
Outdoor and Garden Appliances.
Poultry Houses, Pig and Stock Feeders.
Simple Household and Domestic Articles.
Sycamore Turners.
Toy Making.
Wood Carving.

In previous sections, each chapter has been headed with a list of the uses to which electricity can be put, in the special field covered by the subject. In the case of rural industries, the great difficulty is that multitudinous as the uses [illegible] be, the lack of rural transmission lines mea[illegible] tion of power is rarely made. [illegible]ers.

Most of the foregoing list of nearl[illegible] occupations, could be carried on far more [illegible] are at present by the introduction of mod[illegible] electric power.

Rural Possibilities.

It will no doubt be somewhat of a surpris[illegible] to realise from this list the tremendous poss[illegible] industrial life. Since farming is itself a seaso[illegible] is a very good reason for combining industrial [illegible] cultural life. It would seem that a good rural [illegible] tricity would result in checking the deplorable m[illegible] country to town, which is a problem of the age, not[illegible]

but also in other countries. It will afford the economical opportunity to pay wages to the country worker, that are strictly comparable with those of the town industrialist.

The extended use of machinery in urban districts, coupled with the attractiveness of the town, has drawn many of the workers away from the country. A supply of electric power will ultimately result in many industries returning to the country, especially when their raw materials are conveniently located there, and also when the waste from the industry (e.g., malt culms and spent grain from beer, refuse from sugar-beet, etc.) can be utilised to feed the farm live stock. There are, of course, many difficult problems to be solved, which, in these days of large scale advertising and selling, seem only likely to be overcome by some sort of co-operative scheme. Since much of the work must be done on piecework systems, there may be a danger of sweating. Scattered and unorganised workers are always in danger of exploitation. To guard against this, it is the author's opinion that the setting up of rural factories should be encouraged rather than the institution of cottage industries, as in the case of the former, the operation of the factory acts will preserve the health of the workers, which it is quite impossible to do so long as work is carried out in the home.

Continental Rural Industries.

On Continental farms, it is quite a common thing to find such industries as the manufacture of alcohol, beer, cider and beet sugar, also weaving, lace making, sawing, wood working, etc.

One of the most interesting of French rural industries is that of silk weaving, which is largely carried on in the district to the North-West of Lyons. Looms (electrically driven) have been installed in weaving sheds, built on to cottages or farms and silk weaving is being combined with the industry of the cultivation of the ground. (Fig. 34). A little to the south of this district are found such industries as the turning of wooden handles for carpenters' tools, whilst electric power assists in the manufacture of briar pipes in the Jura mountains and wooden spoons and forks in Savoy. The cabinet makers of the Pyrenees mountains are justly famous, and it is well known that some of the

most successful watch and clock makers are inhabitants of the picturesque chalets and villages perched on the mountain sides of the German Black Forest.

In France, it has been the experience that the introduction of electric power into rural districts, has caused many small industries to spring up like magic. One result of these new industries has been the assured success of the electricity supply undertakings in districts where it seemed likely that the farm load would take a long time in picking up.

Fig. 34.—Silk looms in a house near Lyons.

British Rural Industrial Development.

The author has had opportunities of observing many movements set on foot in this country during the past twenty years to widen village life by the introduction of industries, apart from the purely farmhouse ones of butter or cheese making and bacon curing. Many rural industries owe their inception to the enthusiasm of individuals who have taught and financed these crafts from their first introduction to the district. In other cases, it is a question of the revival of an industry temporarily in abeyance.

Pottery.

Sir Lawrence and the late Lady Weaver have been instrumental in the prosperity of the Ashtead Pottery industry. (See Fig. 35). Here, an electric motor drives the pottery wheels and lathes. Electricity is not used at present, in this instance, for heating the kilns, although it would be most advantageous if power could be obtained cheaply enough for this to be possible.

Fig. 35.—Potter at work on electrically turned wheel at Ashtead.

for electric heating insures easy control over the temperature. What is wanted is a special tariff for this purpose. The author is indebted for this information to Lady Anne Snell. At the Compton Pottery (set up by the late G. F. Watts, R.A., and his wife about thirty years ago) the one black spot on the landscape is the smoke from the furnace used

for heating the drying room. Periodically a heat of 1,300 deg. Fahr. (705 deg. Cent.) is required for the kiln.

For the best class work in china, the cost of the electric current, at any ordinary price is trivial, compared with the uniform success obtained. A few spoiled articles, would cost a good deal more than the electricity, whose use would have saved them.

There are other village potteries where electricity is not available. It can be imagined that the preservation of a continuous temperature of 70 deg. Fahr. (21 deg. Cent.) in the drying room, is a matter of some difficulty with coal or coke firing.

Hurdle Making.

Hurdle making in North Wales has been started on the Lake Vyrnwy estate of the Liverpool Corporation. The industry, which employs about a dozen men, is carried on practically in the open air, as the work-shop consists of very little more than a roof for machinery. A 5 h.p. motor drives a circular saw of 24 inches in diameter, and a 9 h.p. motor drives a 30 inch diameter circular saw. An apparatus for trimming the ends of the cross bars to a circular shape has been manufactured locally. It is found that there is a ready market for these hurdles, the labour for which is paid on a piece work basis.

Irish Lace.

Irish lace is too well known as a cottage industry to need any comments, and perhaps it borders on the sacriligeous to suggest that power should replace hand work there. Nevertheless, if the Shannon Scheme is going to be of real benefit to the Irish rural community, it cannot do better than assist the poverty stricken peasantry to larger incomes, via a greater output.

Wireless as a Village Industry.

There is nothing in the manufacture of wireless sets which renders it imperative for such manufacture to be carried out in the towns. In Surrey, the industry of the manufacture of sets has been started, power being derived from a hydro-electric plant about a mile away, where the water wheel which operated in the times of the Roman and of the Sussex Iron workers has been replaced by a modern electric turbine.

The whole question of the introduction of machinery on a farm, naturally introduces the necessity for some type of rough work-shop to deal with inevitable repairs. This wireless industry, for instance, is an off shoot of such a work-shop. Obviously, where power has been introduced and a little machinery installed, it is a waste of both not to employ them to their fullest capacity. The illustration of the corner of a work-shop in South Dakota shows the possibilities of this idea. (Fig. 36).

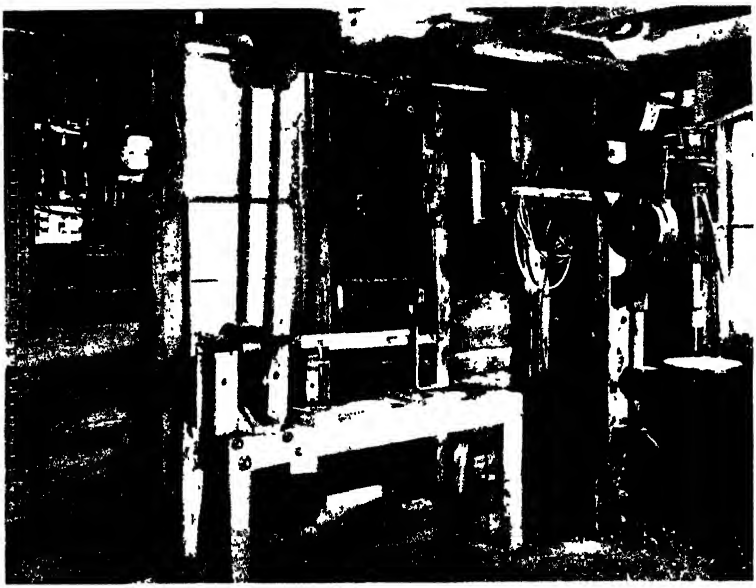

Fig. 36.- An American farm workshop.

The Village Wheelwright.

Serious unrest has been aroused by the lack of prospects facing the village wheelwright. With almost universal railway transport, to say nothing of the competition of factories, the wheelwright finds it very difficult to earn a living by the building of farm vehicles. Obviously, he must enlarge his business by the adoption of side lines. That is to say, he must become the village repairer of farm equipment and the manufacturer of the hundred and one wooden articles, e.g., handles for

hay forks, tools, benches, yokes, tubs, etc., for which the demand is steady. For this purpose the installation of power driven machinery, such as lathes and drilling machines, coupled perhaps, with an electric welding apparatus and forge, is essential.

This outlet for the village wheelwright presupposes that the majority of power and tractor equipped farms have not a workshop of their own, and probably this is a better solution of the problem of farm repairs than the advocation of farm workshops, to justify the equipment in which supplementary industries have to be introduced.

Day Old Chick Production.

In England, the trade in day old chicks is practically confined to pedigree birds, but in America the day old chick trade is a mammoth industry in itself, which has increased by leaps and bounds since the introduction of electric incubators. It would seem that here is a rural industry which might well be developed. The busy season coincides with the slackest period of the farmers' year.

Drying of Fruits and Vegetables.

A drying plant is a useful form of rural industry, and can be economically added to many farms that are electrically equipped. A great deal of farm produce in seasons of plenty is wasted, simply because it does not pay to take it to market. Much of this, when dried, could be profitably marketed at a later and more convenient date. Experiments carried out by the author, show that it does not usually pay to employ electricity as the heating medium for drying purposes. However, on a farm there is usually a collection of rubbish which can be easily burned to provide the necessary heat. Of course there is no better motive power than electricity for the necessary fan drive.

It may be of interest to point out, that only one kind of vegetable or fruit can be dried at a time, owing to the varying degrees of rapidity, at which each variety dries. It is of great importance that drying should be carried out thoroughly and uniformly. The time required for drying is very definite, owing to various factors, such as the maximum temperature the product will withstand without discolouration or loss ; its rate of

giving off moisture, the humidity of the atmosphere, etc. Generally, most fruits and vegetables can be dried in a temperature of 120 to 160 deg. Fahr. (50-70 deg. Cent.) without loss of their characteristic food qualities and flavour.

TABLE XIII.

THE DRYING OF FRUITS AND VEGETABLES.

Material.	Percentage of moisture.	Hours to dry (8 to 12% moisture) about.
Apples	84.6	1
Bananas	—	3-6
Beets	—	1-3
Carrots	—	2½
Celery	94.5	2½
Cereal Crops—Grain straw	14	½
Grass Hay	73	3
Onions	14	3
Parsley	—	½
Parsnips	83	2½
Plums	—	12-14
Spinach	—	1½
Strawberries	90.4	3
Tomatoes	94.3	3
Turnips	93.3	1
Potatoes	78.3	4

About one pound of coal is required per three pounds of moisture in the fruit or vegetables. The author has successfully cured wet green grass by the aid of an electrically driven fan, without auxiliary heating, other than that produced by the natural heating of the rick. (See page 188).

Rural Industries Bureau.

In 1921, a body known as the Rural Industries Bureau, was set up under a Trust Deed. Under the Chairmanship of

Lord Ernle, it soon became actively engaged in the collection and dissemation of information referring to rural industries. The Bureau works in close touch with Government departments as well as with the National Federation of Women's Institutes, the National Council of Social Service, the British Legion and also Labour and Co-operative movements. It has a unique lending library, containing books and pamphlets on the technical, artistic and economic aspects of rural industries. These publications give concise and complete information on the crafts with which they deal. The fact that the Bureau, in one year, answered 2,000 queries, shows that it is performing very useful work.

Rural Demonstration Vans.

The idea of touring the rural districts with a demonstration van is universally acknowledged by rural education authorities. to be a most effective form of propaganda work.

The Ministry of Agriculture, at a cost of about £550 recently equipped a demonstration blacksmith's van, which has been doing useful work in the County of Oxfordshire, under the auspices of the County Council. The Leicestershire County Council have had a demonstration van built for themselves. This is suitable for demonstrating rural crafts and is fitted within with all the paraphernalia, lathe, drilling machine, bench, tools, welding apparatus, etc., of a small workshop. This van was designed in the workshops of Loughborough College and another dairy demonstrating van, fitted with all the latest dairy electrical equipment, will probably be sanctioned at a later date.

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CHAPTER VIII.

WIRING AND LIGHTING OF FARM BUILDINGS.

Decimal Class. 631.2E

The Main Electrical Distributors.

As many farm buildings are old and in a bad state of repair, the main electrical distributors should be run outside the building. An additional reason for this is that many of the barns are often completely filled with crops at certain periods of the year, making it impossible to get at inside wiring when alterations or repairs are necessary. Construction costs are also much lower, while the making of tappings or loops are facilitated. A practice sometimes employed is to run the mains under the eaves and encase them in heavy galvanised steel tubing. While this method gives a very satisfactory installation, it is rather expensive and neutralises some of the advantages of running outdoor mains. However, the author prefers bare overhead ring mains round the buildings. This method has many advantages, chief among them being that temporary and permanent connections can be carried out with a minimum of time and expense. It is this system which the author employs on his farm at East Grinstead. It might be remarked that very little difficulty is experienced in keeping the mains above the highest load of hay carts, etc. Fig. 37 shows the ring main on the author's farm.

In this case the supply is three-phase, which is obtained from a private hydro-electric power station on the farm. The distribution is at 400 volts for power and about 230 volts between any phase and neutral for lighting. Above the three-phase lines a galvanised wire, which is stapled to the pole, is run, and an earth connection is made on similar lines to the practice adopted on standard telephone poles. This serves both as a neutral wire and as a lightning protector. A further advan-

tage of the ring main, is, that the section of copper wire used, is reduced, as the main itself is a closed circuit, and any point is fed from both sides of the connection. Pole fuses of a simple, easily removable type are introduced where the supply main connects the ring main. When the distribution line is installed close up under the eaves, an ample supply of plug connection boxes should be installed. However, with the overhead ring main many of these are unnecessary.

Internal Wiring.

Where steel tubing is adopted it should be of the heavy type covered externally with hemp or similar braiding impregnated with red lead and fish oil, the object of the latter being to keep the coating in a semi-plastic state, so as to better resist the inroads of moisture. Owing to the deleterious effects arising from the ammonia and acid fumes in the humid atmosphere found in stables and byres, the systems of wiring common to industrial buildings are of no use for farm purposes. In fact, the general system of wiring should be more along the lines adopted for use in chemical buildings. For instance, the ordinary vulcanised india-rubber cable is of very little use, even when mounted on insulators and it is hopeless, owing to internal condensation, when placed in steel tubing. Lead or composition sheathed insulated wires are also of little use. A common practice, in Germany, is to use bare wire, mounted on telephone type insulators, placed close under the ceiling. The switches are also mounted on the ceiling and operated by metal turn-rods. Many makes of C.T.S. or T.R.S. cables have not proved nearly as satisfactory as a special form of cable known as maconite. Whatever form of wiring is employed, great care must be taken with the joints and connections to fittings, to prevent ingress of moisture, etc. One firm of cable manufacturers, make fittings arranged to receive a plastic compound, which, while it does not set hard, protects the joints, from the effect of the atmosphere. One very satisfactory method of jointing is by means of thimbles made of insulating material. These are incorporated on a piece of steel spiral wire, which serves as a thread. Such thimbles make a moisture and acid-proof joint. A modification of this type has recently appeared on the market,

it is made of porcelain with an internal porcelain thread. While these are very satisfactory under certain conditions, they have not proved so reliable as the type previously mentioned for general farm work.

The fittings employed for farm purposes should preferably be of the porcelain type, which can be sealed up after connec-

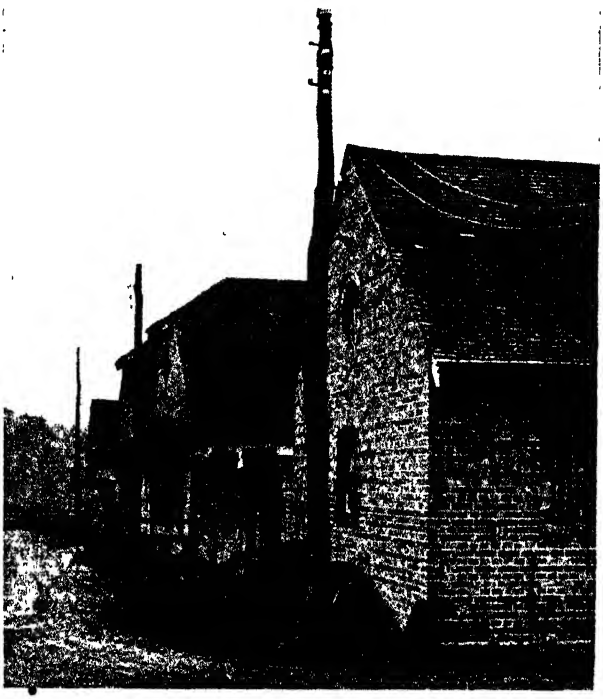

Fig. 37.—An overhead ring main at Greater Felcourt.

tions are made, to prevent moisture getting at the connections. While water-tight enclosed glass fittings are often employed, trouble is sometimes experienced due to internal condensation, a condition which is often met with on farms.

Switches.

Switches, as far as possible, should be outside the buildings, but whether they are inside or outside they should be of the

weather-proof type, to avoid the trouble caused by the humid atmosphere of the buildings and barns, which is often worse than the effect of wet weather. (Fig. 38). Continental practice for plug points favours switch boxes which are designed on an interlocking principle, so that the plug cannot be inserted or withdrawn unless the switch is off.

Fig. 38.—Waterproof switch and meter installation in a barn.

Where internal switches are required the most suitable types are the overhead type, operated by turning handles, and the inverted rotary type with a drip protecting porcelain shield. This latter type is by far the most satisfactory for farm operations and should be used in preference to the tumbler type switch.

Fuses.

The ordinary type of fuse should not be used, as farm workers are too often tempted to use pieces of wire, strip metal, etc., to replace a blown fuse. The "Zed" type of fuse is a more satisfactory one, as it is extremely simple and practically foolproof. This fuse comprises a fuse-fitting or base, a gauge ring, a cartridge and a screw-cap. (Fig. 39). An indicator device in the screw-cap shows clearly which particular fuse has blown, and to change it, all that is necessary is to replace the old cartridge by a new one of the same colour. This colour-scheme, for distinguishing the various sizes of cartridges is a great boon to farmers, as no special knowledge of any kind is

Fig. 39.—A complete "Zed" fuse, consisting of the fuse fitting the gauge ring, the cartridge and the screw cap.

required, and the work can be done by anyone around the buildings. There is also the further precaution against replacing a blown fuse by one with a higher current carrying capacity, for the gauge ring is so constructed that it is impossible to place in it a larger cartridge than that ordinarily needed to protect the circuit.

Wall Plugs.

It is very important that the design should be such that these plugs cannot be fitted the wrong way round, and further it is a good plan to insert a catch which holds the plug in position. It will be found advantageous to interlock the plugs

with the switches, so that they cannot be inserted when the switch is closed or withdrawn unless the switch is open.

Lamps.

A useful standard size of lamp for the farm buildings is the vacuum type metal filament 40-watt size. The efficiency of this size lamp is only a trifle less than that of the gas-filled pattern. The author has found that by installing all lamps of the same size, a great saving is effected as the farm-hands are not tempted to change the lamps from position to position, for the purpose of obtaining a more brilliant light. This often happens when different sizes of lamps are used, with the result that a number are broken. Further, only one size of spare lamp need be stocked.

Lampholders.

The ordinary English two-pin contact type of bayonet lampholder is very unsatisfactory. A better plan is to install the type in which the whole terminal plug holder and its solid, springless terminals, is held in position by a single spring, or what is even more desirable, the all-composition holder. Even here a rubber umbrella ring joint, for the neck of the lamp, is very advantageous. The Edison screw cap lamp seems to serve very well on the Continent.

Reflectors.

One of the ways in which the cost of illuminating the buildings can be reduced, is by careful and scientific arrangement of the light points. Effective reflectors not only bring about economy in consumption but they also provide a much more evenly distributed light. The head-room available in the majority of farm buildings rarely permits of the employment of conical focussing or other similar types, The most suitable form is the modern extensive or distributing type, using a 40-watt metal filament lamp. Where the above type of reflector and lamp is used, the lamps should be suspended between seven to eight feet from the floor and spaced sixteen feet apart. This arrangement gives sufficient light on the floor to carry out the work in comfort. Prismatic glass reflectors are very satisfactory, except that they collect the dust externally and cleaning is often neglected.

A weak point is the design of the holders for these shades, as they are liable to oxidisation, especially the small screws generally

CHAPTER IX.

ELECTRIC PLOUGHING.

Decimal Class. 631.512E

It is still to many people an almost unknown experience to ride, as the author has done, upon a monster electrically operated plough. It is a never-to-be-forgotten sight, to observe seven huge waves of rich red-brown earth, eighteen inches deep and fourteen inches wide, roll over, in a similar fashion to the waves on the sea-shore. This analogy is further emphasised by the rustle of the dry stubble, as the waves of earth turn over. Occasionally a big stone, that has worked its way up from the sub-soil, is encountered. There is a slight jar on the plough, the haulage rope tightens, the pointer of the ammeter, which is installed in the haulage gear, rises rapidly, indicating that the electric motor is exerting over 200 horse power, then in an apparently effortless manner, a huge boulder of some 30 lbs. is unearthed and tossed aside, while the plough continues on its way. Electric motors of 150 brake horse power are used for this work, and up to 30 acres a day can be ploughed, including sub-soiling.

Deep Ploughing.

This is chiefly employed for such crops as sugar beet. Of course, ploughing to such depths is not needed for most crops, though deeper work would be very advantageous in many cases. But little increase, in the depth of a previous ploughing, can be made from year to year, or sour soil, deficient in humus and bacterial life, will be brought to the surface, to the detriment of subsequent crops. Then again many soils are but shallow coatings over rock, which obviously restricts the depth of cultivation.

The question of deeper cultivation is now occupying the attention of leading agriculturists. Many believe that the

practice of relying upon the surface layer of the soil for growing crops, is responsible for a good deal of water-logged land in winter. The effect of the pug marks of horses, the wedging action of plough shares and the pressure of tractor wheels, tends to pack down the sub-soil below a depth of five to six inches, with the result that the crop is unable to draw moisture from the lower layers of the soil and the natural drainage of the land is interfered with. Sub-soiling and deep ploughing are now being tried, to obviate this drawback, and it is claimed that the additional cost of the work is very small when compared with the advantages derived from the practice. Sub-soiling breaks up the hardened pan and improves the drainage, consequently increasing the moisture supply during dry weather. The importance of this has been more fully recognised during the past few years, owing to the introduction of sugar beet, as the beet grows entirely underground, and further has long tap roots, so it cannot develop properly unless the soil is thoroughly broken up.

Importance of Electric Ploughing. :

Work on the land absorbs by far the greater proportion of the total power that is used in agriculture. Hence it is of first importance to consider whether or not the power employed for this purpose can economically be electrical. If all such work were done by this means, the demand for electricity would be enormous.

Now the most important implement at present employed in the cultivation of the land, is the plough. Though it is possible, that when electric power is used to a greater extent, the easier methods of power measurement rendered available, will lead to considerable modifications of this implement, so as to obtain a greater efficiency in operation.

The view is supported by no less an authority than Sir John Russell (of Rothamsted), that until further research has been carried out, it is impossible to say whether the operation of ploughing as at present practised is really an essential part of tillage. In fact little scientific knowledge is available as to the precise mechanical effect of the implements of tillage on the

soil, or what is needed to produce the best results. The design even of ploughs is not stabilised, for in England alone there are well over two hundred varieties, none of which is very suitable for hauling at speeds greater than that of horses.

It is of course difficult to decide on the dividing line between the two operations usually called ploughing and cultivation. In point of fact, the same electrical gear is used for both purposes. For economic reasons the same equipment will be employed for a number of other cultural and harvesting tasks.

Objects of Ploughing.

(a) To loosen, break up and compact the surface soil, so as to provide, after further treatment with other implements, a good seed-bed.

(b) To eradicate weeds and stubble by turning them under the surface, where they will decompose, form a humus, and fertilise the soil for the next crop.

(c) To facilitate the action of frost in producing a good tilth.

(d) To allow aeration and drying of the soil.

(e) To promote drainage by allowing rain to penetrate.

(f) To conserve moisture.

(g) To kill off some deleterious kinds of bacteria and encourage the growth of others which are beneficial.

In the autumn ploughing of heavy clay, the soil should not be pulverised too much, or there will be trouble after the next fall of rain, due to the surface running together and forming an air excluding crust. The seedlings will not be able to push their way through this, neither will further rain or air be able to penetrate. Again, a certain roughness of the surface provides protecting cover for the seedlings.

The efficiency of ploughs is very low, the design of shares and mouldboards being the result of rule-of-thumb development, rather than scientific research. In indicating the practical possibility of changes which may be brought about by the latter, it is interesting to recall that in the course of the War, the efficiency of the aeroplane air screw, which has somewhat analogous surfaces, was increased from 20 to 82 per cent., chiefly

through the application of wind tunnel tests and mathematical research. Many years ago Ransome discovered that plough surfaces should not be of a true, continuous pitch helical form. However, no one seems to have investigated these surfaces by the aid of higher mathematics, though of course much work has been done by trial and error.

The latest development in cultivating implements is the rotary tiller, described later in more detail. While this is likely to have a wide field of use, the plough will probably last for a considerable time yet. One point that seems certain, is, that in designing machines for power operation, horse-drawn types must largely be ignored, and a fresh start made on entirely independent lines. Hence it will be appreciated that a careful consideration of electric ploughing is handicapped by the fact that so little is definitely known about the ultimate results required of the implements.

Types of Plough.

The modern plough is a development of the old wooden plough of which examples are still to be seen in use, in modern as well as in the more primitive countries.

There are two distinct types of plough, the mouldboard plough, and the disc plough. Both are suitable for power work and it is usual to mount a gang of several bottoms together, the number depending on the power available and the amount of work to be done. For rope haulage, a double ended or anti-balance plough is generally used, one set of shares being in use while the other is held in the air, ready to drop down for the return journey.

The disc plough is a newer development than the mouldboard plough. It is very suitable for either very hard and dry or very sticky soil, or alluvial soil, or soils free of stones, especially when difficulty is found in using the more common type. It is, however, unsuitable for heavy land either in a dry or sticky wet condition and also for stony ground. The cutting tool is a disc 24 to 30 inches (61 to 76 cm.) diameter ; it cuts a semi-circular furrow, 6 to 10 inches wide (15 to 25 cm.), somewhat narrower than the mouldboard type, and 12 to 15 inches (30

to 38 cm.) deep. The disc type is largely used in parts of the United States and some of the British Colonies. Though it has not been used for electric ploughing so far, it would lend itself well to this means of haulage in suitable ground. Its rotary action is undoubtedly advantageous in reducing friction, but no attention has apparently been paid to the development of the curvature of the surface of the discs, which should follow somewhat the same principles as those essential in ordinary plough design.

Power required for Ploughing.

The general formula for the Horse Power required has been stated as follows :—

$$\text{Horse Power} = \frac{RWDV}{375}$$

where R = soil resistance in lbs. per sq. in.
W = total width of all furrows ploughed at once in inches.
D = depth of furrow in inches.
V = speed of travel in miles per hour.

Similiarly if R is given in Kg. per sq. dm., W and D in cm., and V in Km. per hour,

$$\text{Metric Horse Power (Cheval-vapeur)} = \frac{RWDV}{27000}$$

The quantity RWD is called the draught of the plough, and when moving at a steady speed it equals the pull exerted by the drawbar of the tractor or the haulage rope.

This formula as it stands is open to question, for many other factors enter into the draught, as mentioned below. An additional constant or constants should be placed in front of R to take these into account.

To find the effect of any factor, all the others must be kept as constant as possible.

Factors Affecting Draught in Ploughing.

(a) Type and condition of soil.
Amount of pulverisation of soil.
(b) Design and adjustment of plough.
Angle of hitch.

(c) Use of coulter.
(d) Employment of sub-soiler.
(e) Width of furrow.
(f) Depth of furrow.
(g) Speed of travel.
(h) Gradient.
(i) Artificial means of reducing draught.

(a) The effect of the soil is called the Soil Resistance. It is measured in lbs. per sq. in. (or Kg. per sq. dm.) of furrow cross-section, and is found by ploughing various soils with the

Fig. 40. Dynamometer for Plough Testing at Rothamsted Experimental Station.

same implement, by the aid of a recording dynamometer. (Fig. 40). The figure obtained always includes the friction of the plough wheels, etc., called the light-running draught.

Recent experiments at Rothamsted show that in one field where the soil appears uniform to the eye, the soil resistance may vary over a range of 40 per cent. The resistance is increased by more thorough pulverisation of the soil. It can be reduced by artificial means, such as chalking the land or passing an electric current from the coulter to the share, as described in section (i). See pp. 140—142.

Table XIV.

VALUES OF SOIL RESISTANCE.

Soil.	Resistance. Lb/Sq in	Resistance. Kg./dm.	Authority.
Sandy	3	21	K
Sandy loam, moist	3-4	21-28	K
"Light" Soil	4	28	B
Sandy loam, dry	4-6	28-42	K
Sandy Clay Loam, moist	5-6	35-42	K
"Light" Soil	5.1-5.7	36-40	R
Bean and Flax Stubble (light dry soil)	5.1-6.6	36-46	S
Stubble (medium dry soil)	5.8-7.2	41-51	S
Sandy Clay Loam, dry	6-7	42-49	K
Clay Loam, moist	6-7	42-49	K
„ „ dry	7-8	49-56	K
"Argileux"	7.7-8.0	54-56	M
Clover Lea (dry soil) medium ..	7.9	55	S
"Medium" Soil	8	56	B
"Heavy" Soil	7.8-8.5	55-60	R
Grass (medium dry soil)	8.6	61	S
Heathland	8.8	62	R
Heavy Clay, dry	9-10	63-70	K
„ „ sod	10-11	70-77	K
Grass (heavy dry soil)	11.2	79	S
Clover Lea (heavy dry soil) ..	12.2	86	S
Heavy Loam (firm state)	12	84	B
4-year Lucerne	12.4	87	R
Virgin Prairie (Clay, moist) ..	12-13	85-92	K
"Argilo-siliceux" (dry)	12.2-16.1	86-113	O
Virgin Prairie (Clay, dry)	14-15	99-106	K
Clay (firm state)	16	113	R
Gumbo, moist	16-18	113-127	K
„ dry	16-20	113-141	K
Adobe, dry	20-25	141-176	K

N.B.—The presence of flints or other stones will of course add to the resistance.

AUTHORITIES.

K = Kranich. Farm Equipment 1923.
R = Ringelmann.
B = Bond. Farm Implements 1923.
O = Ondes Trials, France 1921.
M = Montpellier Trials, France 1923.
S = Shrewsbury Trials, 1921.

(b) The same soil conditions, size of furrow, and speed, will give differing values for resistance with different types of plough, and when the same plough is differently adjusted.

The angle of hitch is most important.

The pull of a tractor may be assumed to be concentrated at the centre of the rear axle, called the centre of pull. Similarly the draught of the plough may be assumed concentrated at a point called the centre of draught, about 12 inches (30 cm.) back from the point of the share, 2 inches (5 cm.) from the landside and 2 inches (5 cm.) above the bottom of the share.

The connections between tractor and plough tend to take up the line joining these two points. If the hitch is not correct vertically, either the share will dig in too deeply or it will not penetrate at all. Further, the line of centres should be parallel to the furrows. This is often impossible in practice, and then, to ensure true running, either a rigid drawbar and brace must be used or crossed, or else A. chains must be employed. These are not essential, if a riding plough which can be steered by the operator is in use.

The worst result of bad hitching is the poor ploughing, which means a loss in crop yield. The draught is not so much affected unless the hitch causes the plough to dig in deeper. Under these conditions tests on a three-furrow plough have shown an increase of 34 per cent. in draught.

Another important point is the sharpness of the plough share. Professor Sanborn has found that a share, repointed and sharpened by a smith, showed 7 per cent. less draught than a dull one, but a new share showed a reduction of 36 per cent. over the resharpened one.

It is to be feared that in many tests, comparing different implements and different adjustments, the soil resistance in

different plots has been assumed to be uniform. Where this is the case, the variations shown to exist in the previous section, may have entirely masked the points at issue.

(c) For tractor mechanical ploughing, knife, skim and disc coulters are frequently used. Where disc coulters are used the soil resistance is reduced and a clean furrow is cut, which can be better turned by the mouldboard.

Professor J. W. Sanborn, in the United States, found for a plough similar to a sod breaker in 2 year old clover sod, that the addition of a disc coulter reduced the resistance from 4.4 to 3.5 lbs. per sq. in. (31 to 25 Kg. per sq. dm.).

In a further test on drier soil, the resistance was reduced from 10.8 to 8.6 lbs. per sq. in. (76 to 61 Kg. per sq. dm.).

(d) The use of a sub-soiler causes a large increase in draught. In experiments at Rothamsted, 6 inches (15 cm.) sub-soiling in heavy clay increased the power consumption 100 per cent. This increase is due to the same cause as that mentioned in paragraph (f).

(e) The draught is proportional to the width of furrow, or the total width of several which are being ploughed at once. With a given plough, Professor Sanborn, found that the draught is least when the plough is cutting the widest furrow of which it is capable.

(f) In the experiments of Keen and Haines at Rothamsted, the draught has been found to be directly proportional to the depth, within the range of 4½ to 6 inches (11 to 15 cm.). Above 6 inches (15 cm.), the normal ploughing depth, it increases much more rapidly than this, owing to the resistance of the hard pan then reached, and sometimes to the variations in the soil composition.

(g) Experiments on the effect of speed have given rather divergent results, but there is no doubt that with present designs, the draught increases with the speed. Thus the horse power, instead of being directly proportional to the speed, increases at a much greater rate.

Tests by the Kansas State Agricultural College, in 1920, showed that an increase of speed from 2.2 to 3.5 miles per hour (3.5 to 5.5 Km. per hour), or 59 per cent., increases the draught

by 75 per cent. in one soil and 66 per cent. in another. With a breaker bottom, an increase of speed from 3.5 to 5.7 miles per hour (5.5 to 9.2 Km. per hour), or 63 per cent., increased the draught by 33 per cent.

On the other hand, tests by Davidson and Collins in Iowa, U.S.A., made in 1920 and 1921, show a much smaller increase in draught. Davidson found that an increase of speed from 1 to 4 miles per hour (1.6 to 6.5 Km. per hour), or 300 per cent., only increased the draught by 26 per cent. to 42 per cent., according to the soil. Collins tested the effect of increasing the speed from 2 to 5 miles per hour (3.2 to 8 Km. per hour), or 150 per cent., and found that with a long-breasted general purpose plough, the increase of draught was 20 per cent., while with a short breaker type it was 75 per cent.

Keen and Haines at Rothamsted, have more recently made some tests with a general purpose plough, which while they cover a smaller range, tend to confirm Collins' results for the same type of plough and Davidson's for the light soil. The points fall very nearly in a straight line, and an increase of speed from 1 to 2.5 miles per hour (1.6 to 4 Km. per hour), or 150 per cent., caused an increase in draught of 14.5 per cent.

These latter results seem to show that the extra cost of current due to the increased draught, will be far outweighed by the saving of both current and labour costs, due to ploughing a given area in a much shorter time.

The difficulties which will arise under present conditions, will be the increased wear and tear on the machinery, and also the breaking up, at higher speeds, of the neat furrows which present designs of ploughs cause. A well-known plough manufacturer has stated, that an increase of speed from 3 to 4 miles per hour (4.8 to 6.5 Km. per hour) may necessitate an increase in the length of the plough breast from 6 to 12 feet (1.8 to 3.7 m.). There seems to be no reason why careful design should not produce the desired end with a less unwieldy implement, but at present, so few data are available that it is difficult to know where to begin. Further, an absolutely unbroken furrow is not a necessity (particularly as the next operation is to break it up); North Country and Continental farmers do not insist on it.

At present electric ploughs usually have speeds of about 2 and 3½ miles per hour (3.2 and 5.6 Km. per hour), which can be increased to 3 and 4½ miles per hour (4.8 and 7.3 Km. per hour) by a change of gear.

(h) The draught is increased by 1 per cent. of the weight of the equipment for each 1 per cent. of gradient. Thus if the gradient is 1 in 40 or 2.5 per cent., and the plant is of the moving tractor type weighing 4,000 lbs. (1,800 Kg.) the draught will be increased by 100 lbs. (45 Kg.). In the case of rope haulage, only the weight of the plough affects the draught, and the effect is very small compared with the total draught.

Fig. 41. Reducing Friction at the Plough Mouldboard by aid of Electric Current.

(i) Experiments at Rothamsted showed that in heavy clay the resistance could be reduced by 15 per cent. by chalking the land.

A recent development is an electrical method which has been used for reducing friction at the mouldboard. This is due to the work of Crowther and Haines at Rothamsted, who carried out a great deal of laboratory work, followed by full scale field experiments at Greater Felcourt Farm, East Grinstead. (Figs. 41 and 42).

A special property of soils is that the soil colloids are electro negative. When a negatively charged plate is inserted in the

soil, the water passes out from the colloid and becomes deposited on the plate. A thin film of water is an excellent lubricant, so it follows that if the plough share is kept negatively charged it is continuously lubricated as it is coated with a film of water. The current can be obtained from a dynamo carried on and driven by the tractor drawing the plough.

Fig. 42.—Dynamometer employed in testing Reduction of Mouldboard Friction by the aid of an Electric Current.

Under laboratory conditions the friction was in the most favourable cases reduced by as much as one-third Owen claims to have obtained a similar reduction in mole draining. While this is a most interesting and important matter, further

experimental work is required, as even the most suitable voltage and current are not yet known

Methods of Electrical Distribution for Ploughing.

Apart from accumulator methods, the supply is almost invariably along the lines shown below, being obtained from public mains

High Tension Line along road or field
|
High Tension Line Tapping
(a) Permanent, or (b) Temporary
|
Portable Transformer Cabin
|

Flying Line (Low Tension)	Flexible Cable. direct to Haulage. (1 or 2 as required).
Low Tension Line Tapping, or Junction Box.	Motors.
Flexible Cable to Haulage. (1 or 2 as required).	
Motors.	

(1) High Tension Line.

Three-phase alternating current is almost invariably used. The larger the motors used, the higher should be the voltage both at the motors and at the high tension line which is tapped. For motors up to about 40 horse power, the high tension supply may come from 1,500 or 3,000 volt lines, and used direct at these voltages or transformed down to 380 or 400 volts. For larger motors it is better to take the supply from 10,000 to 33,000 volt lines.

(2) High Tension Line Tapping.

It is common on the Continent to do this for temporary loads, by means of special hooks having insulated handles and

cables connecting with the transformer cabin. (Fig. 43). These hooks are hung on any convenient part of the transmission line. In theory this does not seem safe, but in practice it apparently works well. It is permitted with even simpler hooks (as the current is but small) on 30,000 volt lines, but the large sets which are supplied at this pressure are always in the charge of a skilled man.

For low tension lines, this method of tapping is allowed in the hands of the more intelligent farm foreman.

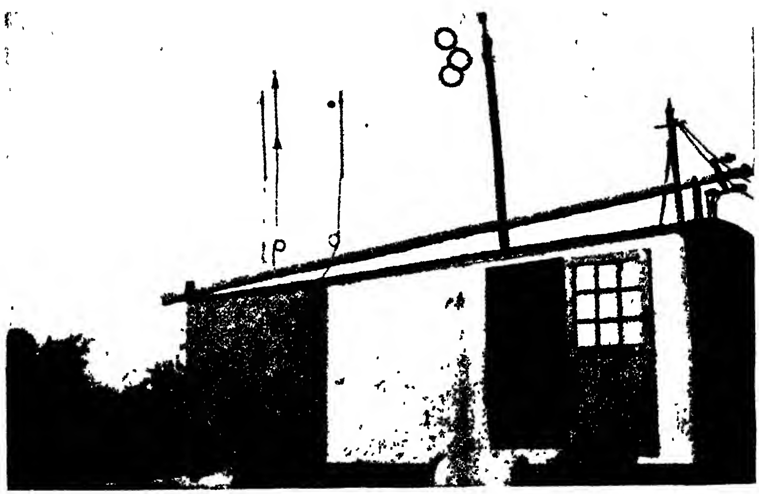

Fig. 43.—The hook method of tapping a 30,000 volt flying line, to feed a 3,000 volt portable transformer for a 125 horse power electric plough.

A safer way is to use one of the foolproof pole contacts which are now available for 1,500 to 3,000 and also 10,000 and 30,000 volt lines. These are very easily operated from the ground by a long rod. They avoid any possible wear and damage to the main transmission line. (Figs. 44-46).

(3) Portable Transformer Cabin.

This usually comprises an equipment similar to the following:-

High Tension Lead-in, consisting of insulators on an iron frame and insulated conductors leading to the High Tension

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Portable Transformer Cabin

Flying Line (Low Tension)

Low Tension Line Tapping,
or Junction Box.

Flexible Cable
to Haulage.
(1 or 2 as required).

Motors.

Flexible Cable.
direct to Haulage.
(1 or 2 as required).

Motors.

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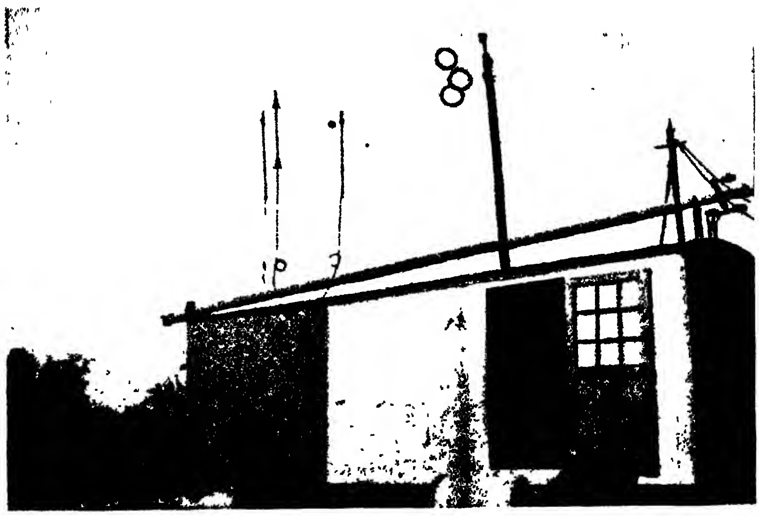

Fig. 43.—The hook method of tapping a 30,000 volt flying line, to feed a 3,000 volt portable transformer for a 125 horse power electric plough.

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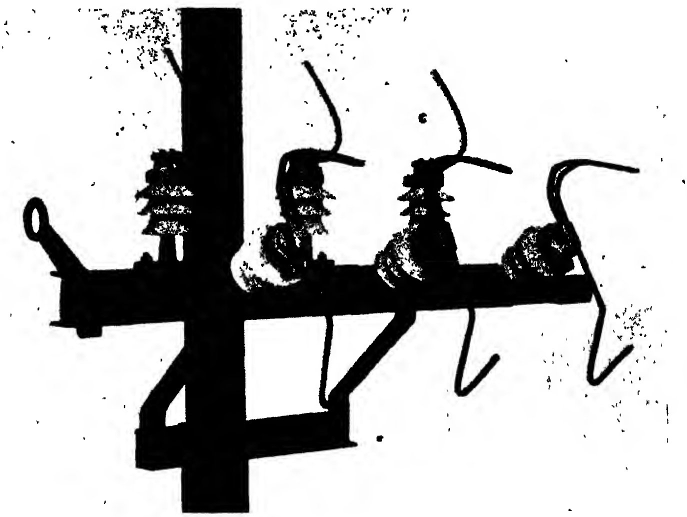


Fig. 44.—Pole Switch for temporarily tapping a 30,000 volt line, open.

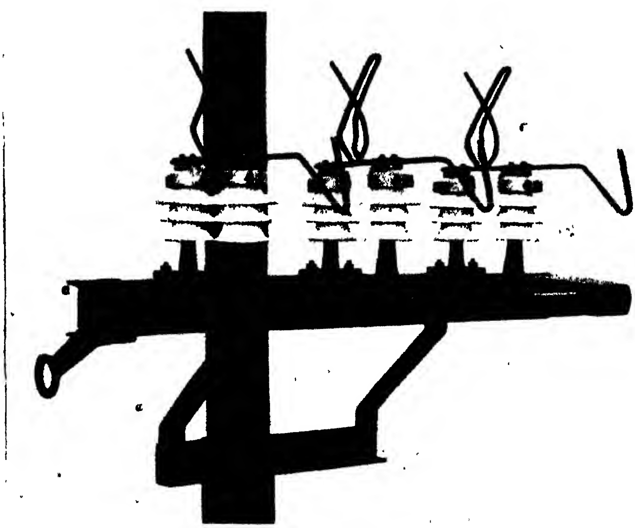


Fig. 45.—Pole Switch for temporarily tapping a 30,000 volt line, closed.

Isolating Links, High Tension Oil Switch, and High Tension reactances. Also a Watt-hour Meter with potential and current transformers and the main Transformer Low Tension Lead-out, consisting of insulators for bare conductors or a socket receptacle for a cable plug.

The instrument transformers for the meter are generally fitted on the low-tension side of the main transformer. Sometimes sleeping accommodation for the men is actually combined with the transformer cabin.

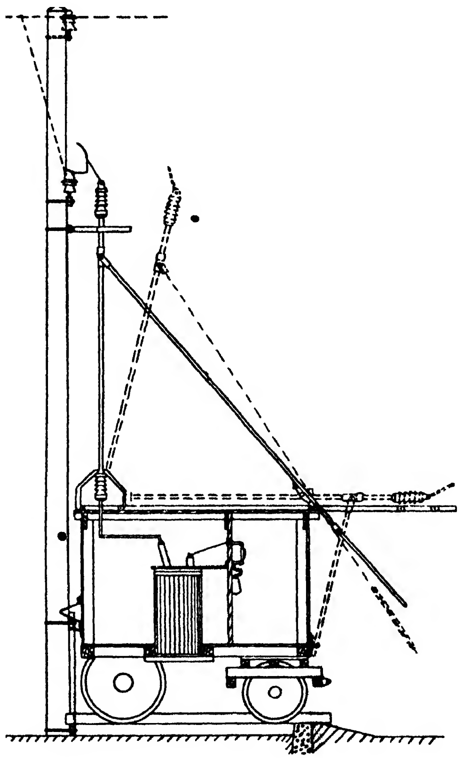


Fig. 46.—Pole Contact in conjunction with Transformer Cabin for 10,000 volt line.

One type of transformer cabin incorporates special safety facilities in connection with attaching the hooks to the H.T. overhead line. A platform is provided, which can be pushed

up through a trap-door in the roof. This disconnects the cabin switch gear from the cables attached to the hooks. When the cabin is placed beneath the line wires, these can easily be reached from the platform. After the hooks have been placed in position on the three phase overhead wires, the platform is lowered again into the cabin, making the hook cables inaccessible and reconnecting them to the cabin switch gear. (Fig. 47).

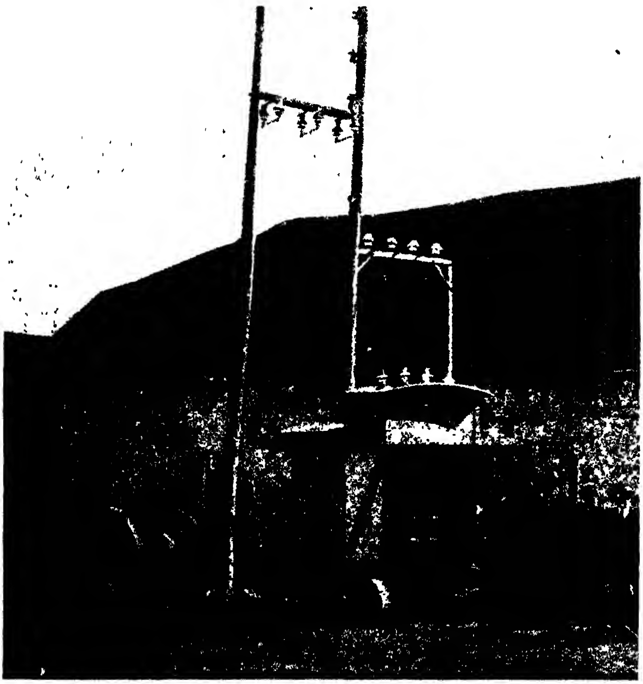


Fig. 47.—Portable transformer cabin, pole isolating switches and flexible cable drum.

(4) Low Tension Supply.

The low tension supply pressure depends, like the high tension, on the size of the motors and the distance between motors and transformer cabin. Usually the motors are wound for 200 to 500 volts, 380 being a common value. In the case of one make of large equipment using from 80 to 150 horse

power motors, the motors are wound for 5,000 volts. To allow for drop in the lines, the transformer should give a slightly higher pressure than that for which the motors are designed.

Depending on the distance, either a flying Low Tension line may carry the supply to a point near to the motors, whence short flexible cables will connect up, or the flexible cables may run the whole distance from transformer cabin to motors. Since the ploughing load is heavy, it can only in rare cases and over short distances be supplied economically direct from a low tension network, thus dispensing with the transformer cabin.

(5) Flying Line.

This is generally economical when the haulage is more than ¼ mile (400 metres) from the transformer cabin. It consists of a temporary or permanent cheaply constructed overhead line. In some cases poles and insulators are erected permanently, and the conductors moved from place to place as required. This method, while saving the labour of moving poles, also saves a considerable outlay on wires.

(6) Low Tension Tapping.

Since the Low Tension current is heavy, except in the case of the 5,000 volt motor equipment, a more solid method of connection to the flexible cable than loose hooks is necessary. A hook clamp intended for low tension service is shown in Figs. 48 and 49, open and closed.

A very simple method is that designed by Estrade for a flying line without insulators. Three short, flat, iron bars are clamped to the pole, each being connected to a line wire. A rod which can be reached from the ground is provided. At the top are three spring clips which can engage with the contact bars already mentioned. Bound to the rod is a three-core flexible cable, one core of which is connected to each of the spring clips. By means of guides on the pole, it is easy to make and break contact from ground level.

Another method is to have a socket contact fixed on the pole within reach of a man on the ground. An insulated cable is led down to this from the overhead wires, and a plug, attached to the flexible cable, is inserted in the socket when required.

Fig. 48.—Hook for temporary Low Tension Tapping, open.

Fig. 49.—Hook for temporary Low Tension Tapping, closed.

(7) Flexible Cables.

There will be one or two flexible cables depending on whether the system of haulage uses one or two sets of winding gear. If two sets are used, it is usual to have one cable only leaving the flying line or transformer cabin, and leading to a point equidistant if possible from the two haulages. Here a junction box is placed, from which the cables feeding the two haulages radiate.

Several types of flexible cable are used by different makers. For 5,000 volts a rubber-insulated armoured cable is used, protected with impregnated yarn.

For lower pressures armoured cables are not generally supplied, the cab tyre sheathed type being very satisfactory. An earthed core or encircling braided sheath is sometimes provided, but owing to the difficulty of getting a good earth, it does not seem to be worth the extra cost.

The method of dealing with the flexible cable is one of the most important points in which the systems of ploughing, set out below, differ, especially in the case of tractor ploughs. The all-important point, as regards insulated cables, is to insure that they are not dragged at all over the surface of the ground —they should simply be laid down and then picked up again.

Equipment.

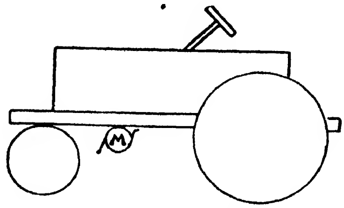
The systems employed may be classified into Tractors and Haulage sets, any of which can be used with either a plough or a rotary tiller (or alternatively in due season with cultivators, farmyard manure spreaders, artificial manure distributors, seed drills, rollers, or harvesting implements).

(1) Types of Tractor Drive.

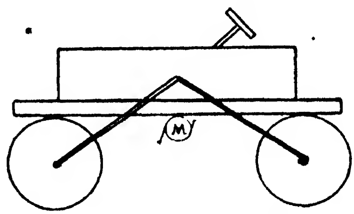
In tractors of the rear wheel drive type, in order to get sufficient adhesion for the drive, the weight must be taken chiefly by the driving wheels, and though these are fitted with strakes or spuds, the weight has to be considerable. As a result, even if the wheels are made as wide as is practicable, the pressure per sq. in. on the soil in many designs is too great, amounting to as much as 25 or 30 lbs per sq. in. (176 to 211 Kg. per sq. dm.) with a one inch (2.5 cm.) sinkage. Such pressures cause pack-

ing of the soil and the formation of the objectionable "hard pan" below the depth ploughed. Further, when the land is very soft, the sinkage may be so great that the machine cannot be used at all. For this type of drive, the weight on the rear wheels, to give reasonable pressures of 15 to 20 lbs. per sq. in. (105 to 141 Kg. per sq. dm.) with practicable widths of wheel, should not exceed about 1 to $1\frac{1}{2}$ tons.

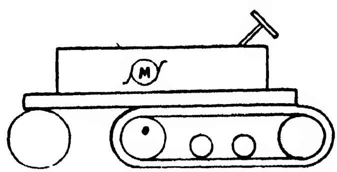
Ordinary rear wheel drive.



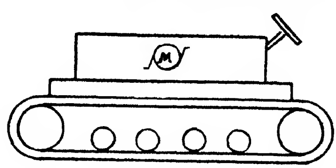
Three or four wheel coupled drive.



Half creeper track and front or rear steering wheels.



Full creeper track.



Another method is to distribute the weight and drive more or less evenly over all three or four wheels of the tractor, these being coupled together. By this means enough adhesion is obtained with the weight much less concentrated and the pressure per sq. in. can be reduced.

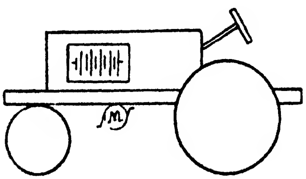
The next step is to use a half-creeper track which takes the drive and the greater part of the weight. By the use of

this method the pressure on the soil can be reduced to as little as $4\frac{1}{2}$ to 5 lbs. per sq. in. (32 to 35 Kg. per sq. dm.). A more usual figure is about 10 lbs. per sq. in. (70 Kg. per sq. dm.). It would be possible to distribute the weight over a still larger area by using an all-creeper track. The first designs of these had no lateral flexibility, and had to skid over the ground to steer, tearing it up severely. Later designs overcome this, and employ various methods of laying the track in a curve. For a general purpose tractor, however, it is preferable to use only a half-creeper track and retain a pair of wheels, either front or rear for steering. These should be rubber tyred.

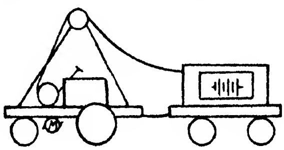
Electric Tractors with Accumulators.

Class (11) Electric tractors using an accumulator, depending on the soil for tractive effort.

Tpye (111) Accumulator carried on tractor.



Type (112) Accumulator carried on separate truck, hauled by the tractor to which current is supplied. When ploughing, the accumulator truck can be left at the side of the field.



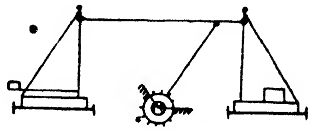
Where the accumulators are carried on the tractor, type (111) with a rear wheel drive, it has been found that the weight is too great and the soil compression and sinkage on soft land is excessive.

A suggestion has been made in France to use an accumulator on a separate truck, type (112) feeding the tractor by a trailing cable, or a combination of flying overhead line and trailing cable. The truck would be hauled by the tractor to and from the charging station and left at the side of the field during ploughing. This partly overcomes the objection of weight, the most satisfactory arrangement is only to depend on the accumulator for transport and to use current from the supply mains when on the field.

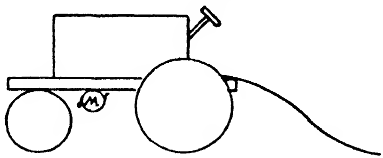
Electric Tractors using an external supply.

Class (12). Electric Tractors connected to supply mains, depending on the soil for tractive effort.

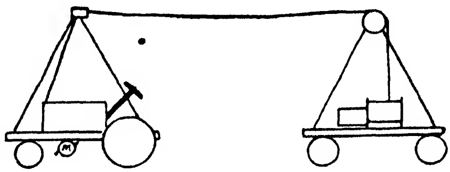
Type (121) Electric tractor with tram car type trolley and movable overhead bare conductor.



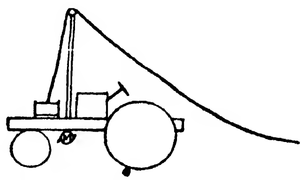
Type (122) Electric tractor with cable reel at side of field.



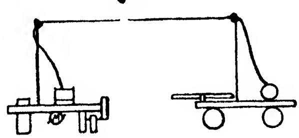
Type (123) Suspended bare conductor feed, with automatic friction-controlled winder on a stationary feeder wagon.



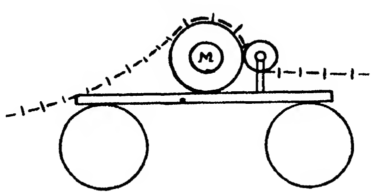
Type (124) Flexible cable with automatic cable winder on tractor, so that the cable is not continually dragged on the ground.



Type (125) Electric tractor with trailing cable, automatic reel on tractor and automatically movable self-winding supply point at centre of furrow.



Class (13) Electric tractors hauling on a chain laid across the field.



Tractors with rear wheel drive and a trailing cable with no special winding arrangement, type (122) have not been found satisfactory in practice. The weight of the tractor though not

so great as the accumulator type is enough to cause serious compression of the soil and difficulties on soft soil, when carried on ordinary wheels.

Again, the trailing cable, lying on the ground immediately behind the tractor, is easily run over and damaged, it is also

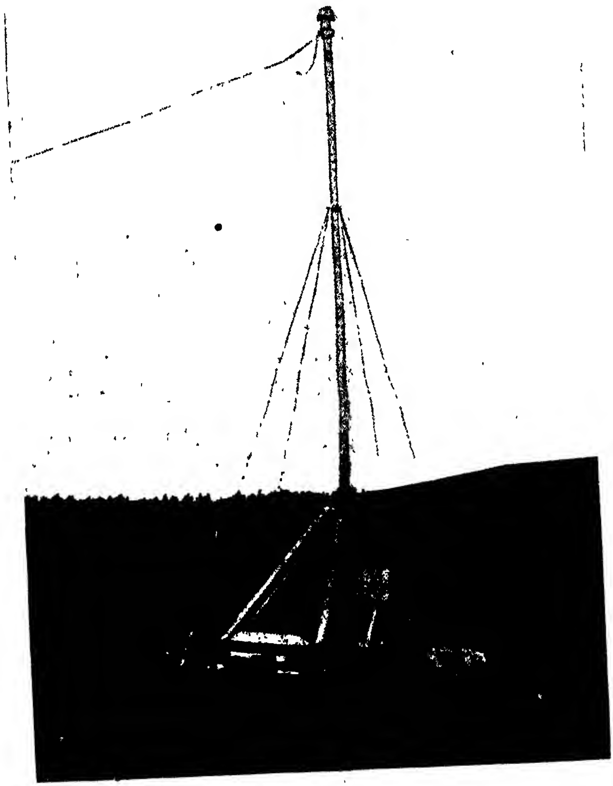


Fig. 50.—A Swedish Electric Plough with Bare Overhead Conductor. Class 123.

worn by being dragged across the ground, so that its life is very short.

The suspended bare conductor feed, type (123), is typified by the Swedish made "Electrotank." (Fig. 50). In this

equipment, an insulated cable runs from the transformer cabin to a special cable trolley. From a mast on this, a bare, three-phase overhead line runs to a mast on the tractor itself.

The cable trolley is anchored at a suitable point for supplying the whole area to be ploughed. It carries an automatic reel for winding up the overhead line, driven by friction, from a motor which is kept continuously running, so as to keep the overhead line always at a definite tension. At the top of the

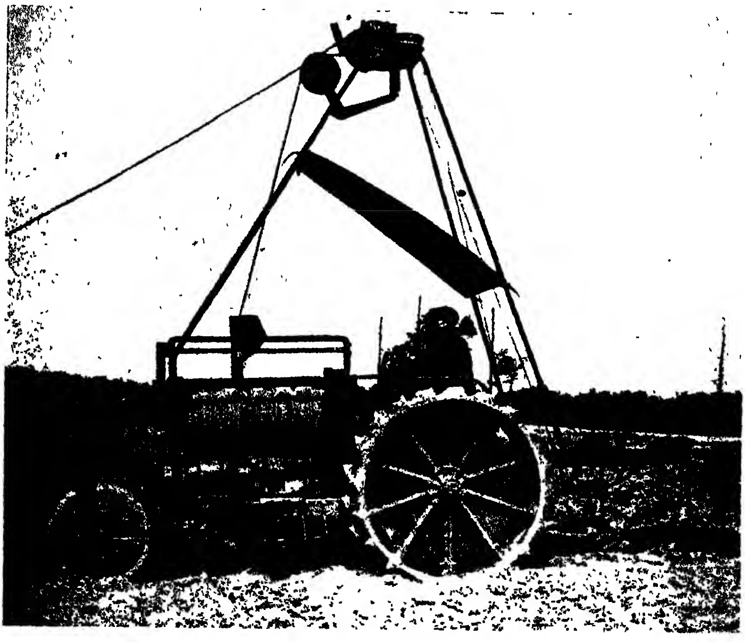


Fig. 51. A Flexible Cable Fed Tractor, type 124.

mast, is a pulley for the outgoing line. The whole of this equipment can swivel into any position, as the tractor moves about.

The overhead line consists of three bare, tough aluminium alloy strips spaced at frequent intervals, with strips of insulating material. The normal length is 800 ft. (250 m.).

The tractor is fitted with a full creeper track and its mast is about 19 ft. (6 m.) high; for passing under telephone wires, etc., the latter can be tilted to 45 degrees. The motor is a 500

volt, 15 horse power, 3 phase induction type and propels the machine normally at a speed of $2\frac{1}{4}$ miles per hour (1 metre per second).

A flexible cable-fed tractor, equipped with an automatic cable winder, in which the cable is raised on a mast, so as not to be continually dragged on the ground, type (124) has been designed by N. Forssblad in Sweden and represents a considerable improvement in electric plough design. The tractor has ordinary straked wheels and the plough is either integral with the motor or attached behind. (Fig. 51).

The main driving motor is 24 horse power, three-phase, with controller and oil switch. A separate motor is provided for automatically winding the cable reel. This motor is provided with a special hysteresis control rheostat. When the tractor is driven away from the source of supply, the cable is drawn out against the friction drive. When the tractor returns, the cable is slackened. As the resistance to the motor drive is thus removed, the motor comes into operation and winds up the cable until it reaches a pre-determined tension. Owing to the hysteresis control, the operation of the motor is automatic; further, it will not burn out when the tractor stops or the cable drum reverses.

A derrick mast about 15 ft. (4.5 m.) high is supported on the chassis, and carries at the top a pulley fixed to an arm which can turn about the mast. This pulley receives the incoming cable and a second pulley guides it on to the drum. Between these two is placed another pair of pulleys, with vertical spindles and the cable passes between them. Thus the part of the cable nearest to the tractor is raised well above the ground.

The capacity of such a tractor, with 3 shares, is about 6 acres ($2\frac{1}{2}$ ha.) per day to a depth of 8 inches (20 cm.) with a consumption of about 28 units (kWh) per acre (70 kWh. per hectare).

Major A. McDowall has recently developed, in Scotland, a new type of electric plough, type (125), which entirely avoids any dragging of the cable. It includes a method of lifting the whole machine sideways, at the end of each furrow, ready for the next. The flexible cable carried on the tractor, need only

be half as long as the furrow and it is automatically unwound and wound up again in the same straight line, thus avoiding all damage by dragging or over-running. (Fig. 52).

The flexible cable is fed from a special feeder cable trolley, which runs along a line at right angles to the furrows and equidistant from either end of them. Another cable, which may be of any desired length, connects this feeder trolley to the farm distribution line and is automatically wound up, by the pushing back of the trolley by the plough, each time it passes the trolley. Undoubtedly this is the best system that has been devised for feeding a tractor type of plough. A full single

Fig. 52.—Electric Plough, developed in Scotland, by Major A. McDowall. Type 125.

creeper-track is fitted to the machine to distribute the pressure on the soil.

It should be noted that this tractor is a reversing type and is fitted with a set of plough shares at each end. This principle, which could also be applied to rotary tillers, saves turning the machine. It is made possible by the use of either a full creeper-track as in this case, or a four-wheel drive steerable from either end.

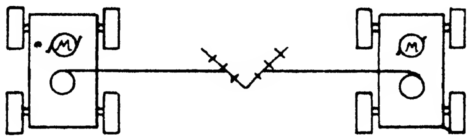
An alternative means of using tractors has been tried, in which a chain is laid across the field and anchored at the ends, Class (13). The tractor propels itself by hauling on the chain

in a similar manner to the so-called floating bridges in use on many navigable rivers. The chain must be moved forward after each operation. This can, of course, be arranged to be done by the tractor. The idea underlying this, is that the tractor can be made lighter since it has not to depend on gripping the soil for its tractive effort. A flexible cable feed is required as used with other tractor systems. In practice this method has not found very wide application. It introduces the complication of anchorages without removing the weight of the haulage from the soil as the double haulage and round-about systems do.

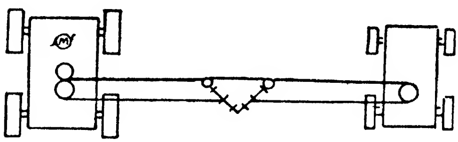
(2) Steel Wire Rope Electric Haulage Systems.

Class (21). Moving winding gears.

Type (211) Double-rope system, with two single drum winders, one progressing up each side of the field.

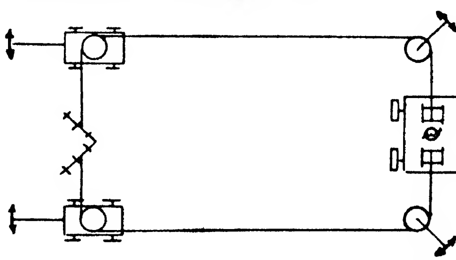


Type (212) Modified double-rope system, with one progressing double-drum winder, and a progressing anchor carriage at the other side of the field.

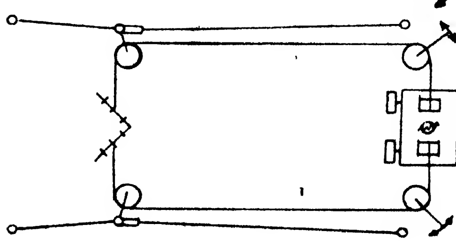


Class (22). Stationary Winding Gears.

Type (221) Round-about or anchor-pulley rope system, with one stationary double-drum winder, and anchorages at the corners of the field, two holding fixed pulleys, and two holding progressing pulley wagons.



Type (222) Modified round-about system, with movable clamps holding fixed pulleys on an auxiliary steel anchoring cable instead of pulley waggons.



Wire rope haulages have two main advantages. The weight of the tractor does not pass over the soil, and the plough is reversible, thus saving the time needed for travelling over the headlands in turning a tractor. (The moving of the haulages or anchorages along the headlands is done alternately, the idle one being moved while the plough is travelling away from it).

The limiting factor in furrow length is usually the difficulty of signalling. For stopping and starting, either arm or flag signals are made, or a horn, a syren, or a whistle is blown. Fog, and intervening hills, wind, etc., may prevent any of these signals being used over long distances, and in practice the length cannot greatly exceed a quarter of a mile (400 m.).

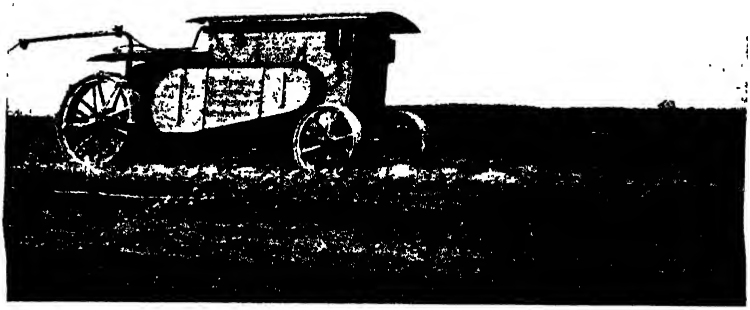


Fig. 53.—The Double Rope System, with two Electric Haulages. Type 211.

Among the disadvantages may be mentioned the extra power needed due to the friction of the ropes on the ground. This friction also means heavy wear and tear on the ropes, especially on undulating ground and damp sandy soil. Another disadvantage of these types of ploughing tackle is their great weight which prevents their use in wet weather, as the headlands then become too soft to travel upon.

The double-rope system with two electric haulages, type (211), is very successful in practice. (Fig. 53). Some of the larger types have certain disadvantages, such as the great weight —about 14 tons for each winder—though this is only applied

to the headlands. Also wide headlands are needed on both sides of the fields. On account of this latter point, the method is chiefly suitable for large areas of comparatively poor land. This type of equipment is more adapted for use by ploughing contractors or farmers' co-operative societies, as its capital cost (from £1,000 to £5,000 according to size), is too high for a single farmer. Its capacity for work is enormous, from 8 to 30 acres

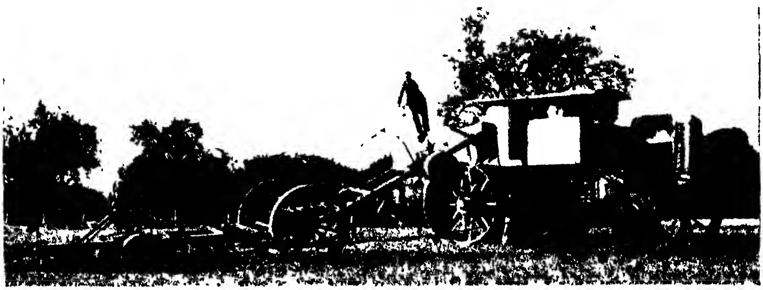


Fig. 54. Reversing direction of balance plough, type 211.

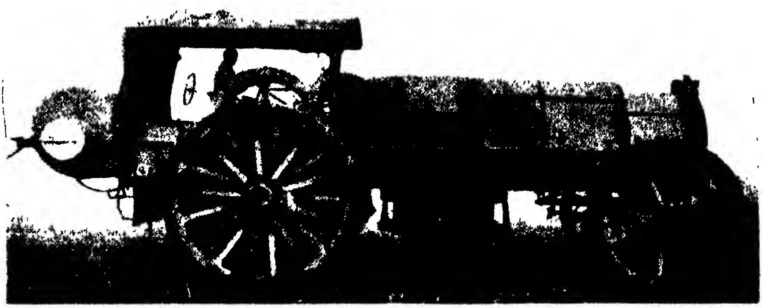


Fig. 55. Large electric haulage, type 211.

(3 to 12 hectares), per day can be ploughed as compared with barely one acre (0.4 hectares) for a team of horses. Owing to the high voltage usually applied to the motors of the larger machines of 100 to 150 horse power, a skilled man in charge is necessary.

The Societé Generale Agricole equipment for this class of work, is supplied with 4 to 9 furrow balance-ploughs, with or

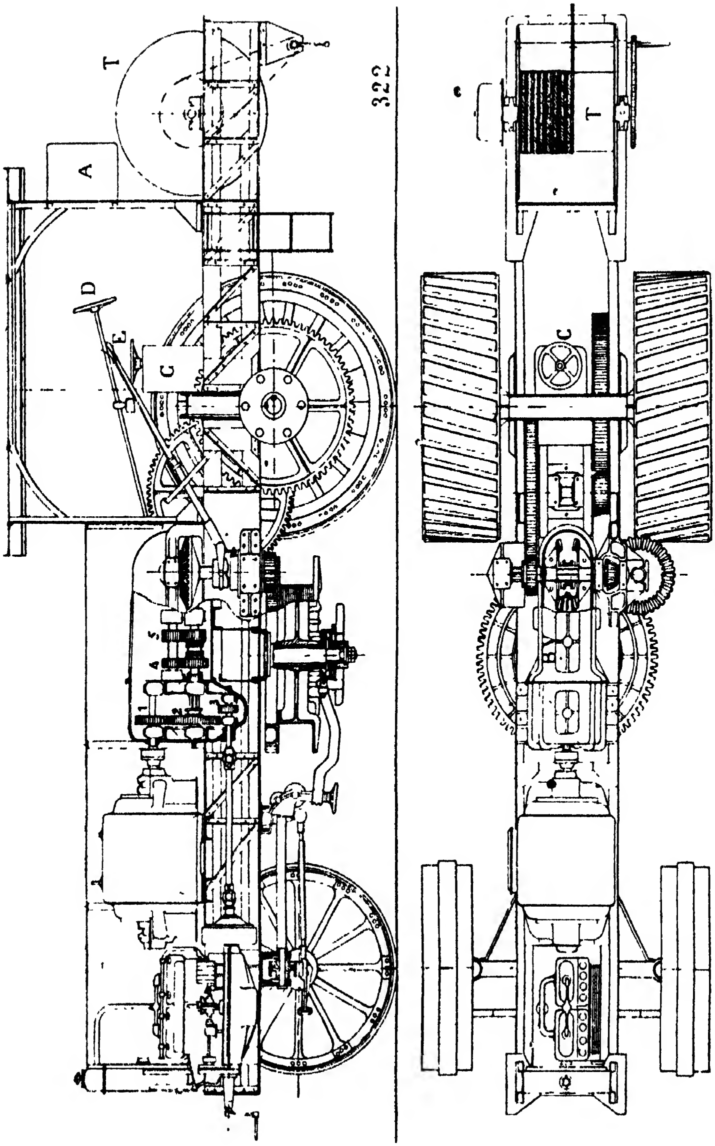


Fig. 56.—Large electric haulage, S.G.A. Equipment, type 211.

without sub-soilers, and up to a 24 tine cultivator. It is guaranteed to plough 25,000 acres (10,000 hectares) in a season Owing to the weight of the haulages, no other anchorages are necessary for them. 50 horse power petrol engines are fitted for transport purposes, when out of reach of electric supply lines. (Figs. 54-56).

Another popular electric ploughing outfit of this type is to be found in use in Italy. It is made by Messrs. Fratelli Violati-Tescari, at Milan. The equipment consists of two electric haulages weighing about 55 cwts. (2,794 Kg.) each. They are four-wheeled vehicles, the two front wheels being the steerers. The motors are of 30 horse power and are placed on the forefront of the vehicle. A speed reduction gear is incorporated and the drum paying out the cable can be operated to as low

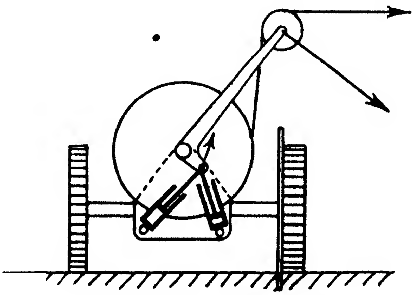


Fig. 57.—Estrade Anchorage.

as 30 revolutions per minute, if necessary. The motor is of the enclosed type and a steel cabinet containing all the controls and instruments, and space for an operator, is fully protected from the elements. A four-furrow balance plough is supplied with the equipment and the cost of the whole outfit is in the region of £1,150, this figure including a portable transformer. It is capable of ploughing about 8 acres (3 hectares) in a ten-hour day. Three men are required to operate the set, one in each haulage and one on the plough. The makers claim that the average cost per acre of ploughing with this equipment is about seven shillings.

Another equipment, used in France, is that designed by Estrade. This is much lighter and less expensive, and naturally covers a smaller area per day—about 6 acres—(2½ hectares)

in eight hours. The motors are of 35 horse power, three-phase, squirrel-cage type and, when desired, can be coupled to the wheels so as to move the haulage, as long as it is connected to the supply. Two speeds are available, 2.75 and 1.83 miles per hour (4.4 and 2.9 Km. per hour).

Temporary 500 volt overhead lines are used, trailing cables being attached at certain tapping points.

This equipment is notable for a very ingenious anchoring arrangement which permits of comparatively light weight haulages. (Fig. 57). The haulage cable passes over a pulley at the end of a pivoted arm. The greater the tension on the cable, the lower will be the position of this arm and the point of

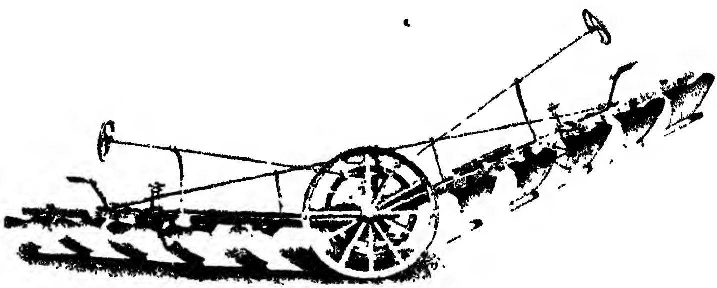


Fig. 58. – 5-share Balance Plough.

application of the pull. The downward movement of the arm is resisted by a system of oil dashpots, so that for every value of the pull there is a position of equilibrium, such that the resultant of the pull and the weight of the haulage always passes through the line joining the points of contact with the soil of the two inside wheels.

The wheels are fitted with flanges, which with the rims, enclose a prism of earth. Thus instead of depending on the friction due to the weight of the machine on the earth, the much greater friction of this compressed prism of earth on that lying beneath is utilised, giving great stability.

Some of the large German electrical engineering firms also supply a two-motor equipment. These usually have 80 horse power motors, for 750 volts, three-phase supply. These motors

are used both for hauling the ploughs and moving the haulages along. No petrol engine is provided for moving from place to place, when disconnected from the supply.

The cost of a complete equipment including two haulages and transformer vans, cables, plough, etc., is about £4,500.

Five-share balance ploughs are generally used, having a working width of about 6 ft. 6 ins. (2 m.) and a working depth of about $8\frac{1}{2}$ to 16 ins. (21 to 40 cm.). (Fig. 58).

With these sets, current consumption as low as 15 units (kWh) per acre (37 kWh. per hectare) is claimed for depths not exceeding about 6 or 7 inches (15 to 18 cm.). This is an

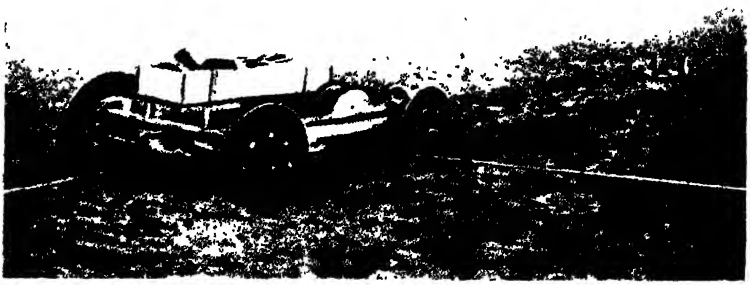


Fig. 59. -Anchor wagon loaded with scrap-iron.

exceptionally low figure as compared with other equipments.

The single winder system, type (212), is intended to reduce the costs of the double winder system. In cost and size, it is a compromise between the double-winder and round-about system. An anchor waggon of special design, with wide cutting flanges on the wheels, usually loaded with a considerable weight of ballast, is used at the opposite side of the field, thus dispensing with one of the winders.

For any particular case, the two methods must be judged in the light of the work required of the set.

The French anchor waggon designed by Boyer is much lighter than the German ones and is intended for use with much smaller motors. It can be loaded with scrap iron, etc., when its own weight is insufficient. (Fig. 59).

Another ingenious French anchoring device is that of Pelous. (Fig. 60). This is used for smaller areas, as the arrangement will not stand so large a pull as the waggon type, and the plough returns light. The clamping device is shifted along the cable at each traverse.

The author is indebted to Guédeney of La Compagnie d'Enterprises Électro-Mécaniques, for turning his attention to

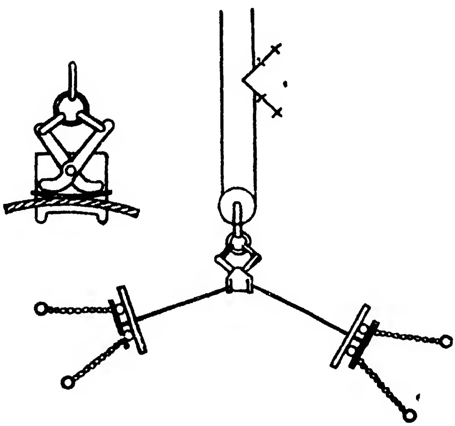


Fig. 60. Pelous Anchorage.

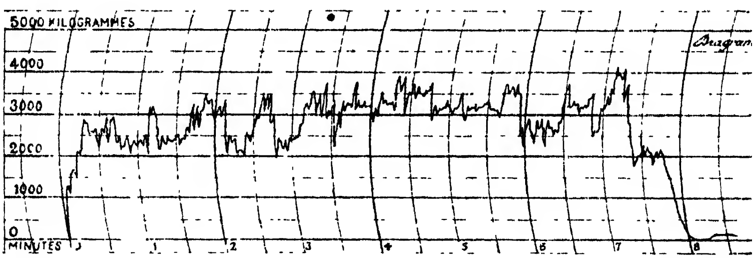
the round-about anchor-pulley method of ploughing, type (221), which, though very old from a steam-tackle point of view, is comparatively new as an electrical method.

The great advantage of the modern round-about system, is that the haulage gear has only to be brought into a field, after which it operates from that stationary position, thus avoiding the movement of heavy haulage sets on headlands. Not only does the use of headlands waste space, but also in wet weather they are often too soft to permit of work being done.

The modern electric round-about system differs from the obsolete English method, in that the mechanical methods of anchoring are very greatly improved. More labour is involved

in setting a round-about system to work for the first time. However, the capital investment is much lower compared to the double haulage method. Further, if permanent anchorages are installed, the objection as regards the labour of setting out is minimised.

The tackle comprises a single electric motor with two haulage-rope drums, either of which can be driven by the motor, as desired by the operator, while the other pulley pays out rope. The haulage rope is arranged, by the aid of suitable pulleys, to follow round the sides of the field to be ploughed. At two corners, anchored angle pulleys are provided. At the other two corners, pulleys are mounted on waggons, from which an anchor rope is taken to the end of the field. When the haulage rope is pulled, the waggons are drawn along to the extent permitted



3 Furrow Plough. Depth of Furrow = 12 ins. (30 cm.).
Total width of the 3 furrows = 3 ft. 9 ins. (115 cm.).

Fig. 61.—Diagram showing variations of pull on a plough in the course of a single journey.

by the slack in their anchor ropes. The balance-plough is attached to the haulage rope between the two pulley waggons. The method of ploughing is to haul the plough from one pulley waggon to the other. The balance-plough is then turned over ready for the next set of furrows. Before starting the new run, the anchor rope of the further pulley waggon is slackened out, thus permitting this waggon to advance a distance equivalent to twice the width of the new set of furrows. The plough is then drawn over to this further pulley waggon and so on.

This system is much more suitable for the average farmer to purchase, or for groups of three or four neighbours, since the capital cost is much smaller.

To the supplier of current, the fact that the motor need not be larger than 30 horse-power is a great point, for the peaks of four 30 horse power motors are much better distributed than those of one 120 horse power motor. Since they will nearly always work at full load, the power factor will be good. The variations of pull on the plough in the course of a single journey are shown in Fig. 61.

The comparative lightness of the tackle means that it will not be so liable to sink in wet soil and its season of usefulness is prolonged. The haulage does not pass over the land ploughed, since it only enters one corner of the area and does not move, while about 40 acres (16 hectares) are ploughed,

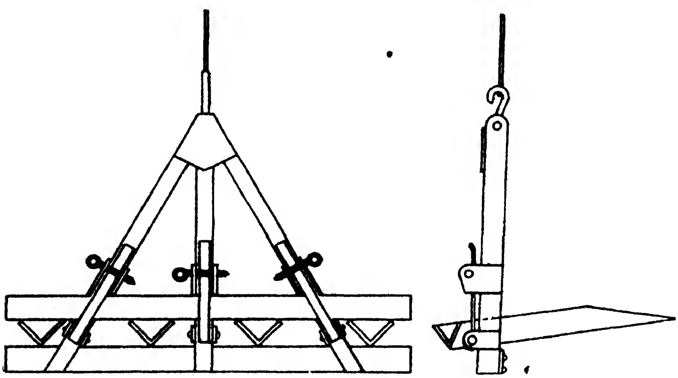


Fig. 62.- Guedeney Anchorage.

only the anchor waggon chains being slacked out. For this reason it can often be placed near the transmission line, saving cable and labour costs.

The number of anchorages required is rather a disadvantage. They are based on the action of the stockless anchor of a modern steamer; but the equivalent to the flukes is separate, and consists of pointed angle irons. These are driven into the ground separately through a special frame, which acts as a stock. When it is desired to take out the anchor, a trip is knocked out on the stock; a strain is then put on the rope by the haulage gear, the anchor opens out and is thus easily pulled out of the ground. (Fig. 62).

In a simplified form of the system, due to Douilhet, type (222), using motors not exceeding 25 horse power, the anchor waggons are displaced in favour of the two simple pulleys and the anchorage is obtained by pieces of timber buried horizontally about 35 inches deep (90 cm.) (Fig. 63), with chains attached. By keeping the power small, all fear of shifting the anchorages is avoided. This type of plough, adapted for use with a 12 horse power motor, is now in use on the author's farm at East Grinstead. (Figs. 64-66).

For fields ploughed every year, it is economical to leave the angle irons or the logs of wood permanently in the ground, as the time saved much more than outweighs their small cost.

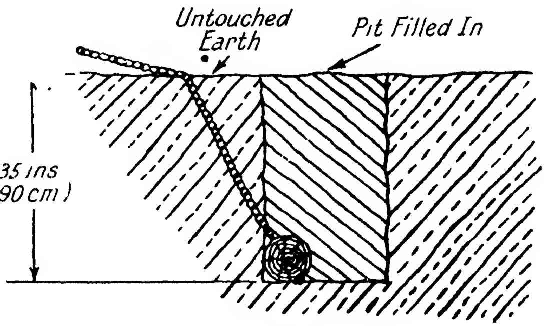


Fig. 63. —Douilhet Anchorage.

The author has devised a method by which the round-about system can be entirely controlled by one man riding on the plough. For this an insulated copper core is included in the haulage rope, and contactors controlled by a push-button operate the electrical gear.

The round-about equipments are much lighter and easier to handle than the other systems described, and only require two men to operate them when once set up in a field. Lately some very small rope-haulage electric ploughs, of only a few horse power, have been put on the French market for work in vineyards. (Fig. 67).

Transport of Ploughing Equipment.

This is accomplished by :

(a) Horse or Oxen.

(b) Accumulators (either incorporated in the winders or mounted on a separate truck).

(c) Petrol engines incorporated in the winders

(d) Separate oil engine tractors.

(e) Placing the equipment (by aid of its own power) in Petrol Lorries.

The Ideal Equipment.

As a result of his investigations the author has come to the conclusion that the most suitable electric equipments for use under different conditions are as follows :—

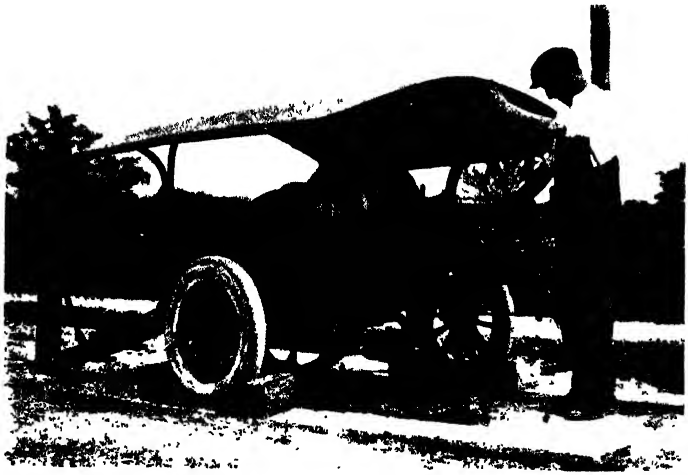


Fig. 64. The Haulage Equipment for Electric Ploughing at Greater Felcourt, East Grinstead. Type 222.

(a) For contractors working over large areas in the course of a season, the steel wire rope haulage systems, Class 2, will generally be found most satisfactory.

(b) For the individual farmer on a farm of 150 to 200 acres (60 to 80 hectares) upwards, the best method will usually be an electric tractor with a half-creeper track and a combination of Class 11 and Class 12, i.e., a flexible cable raised above the ground with automatic winding, using a storage battery for transport and employing current from the supply mains when on the field.

As far as the tractor is concerned, this must be an all-purpose tool. It must be able not only to plough for wheat and similar crops of the Western Hemisphere, but also to cultivate between rows of vines and of orchard fruit trees and to plough the paddy and sugar cane fields of the Far East. To enable it to hoe growing crops it must have a high ground clearance so as to pass over the crops (e.g., maize and roots) without damaging them.

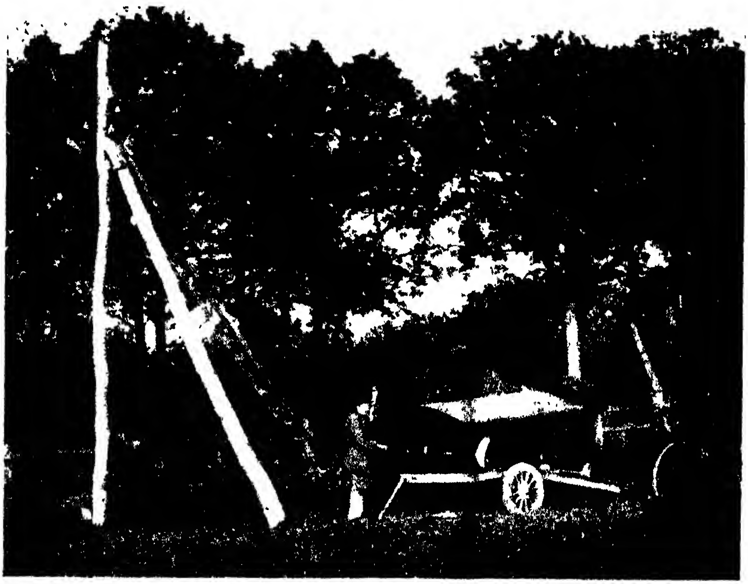


Fig. 65.—Connecting Electric Ploughing Equipment to Power Mains at East Grinstead. Type 222.

Though the tractor is universal, the implements used behind it will vary widely, and in ordering an outfit it is important to mention local soil characteristics, class of farming, depth of ploughing, makes and types of ploughs in use, not forgetting, of course, the system and voltage of electric supply available.

The equipment must for economy be controlled by one man. The tractor principle is advantageous because it avoids the work entailed by anchorages, as used in round-about systems.

The storage battery will serve for moving the equipment from field to field, and also enable the tractor to be used as a general purpose vehicle, for haulage on the public roads and about the farm when out of reach of an overhead line. This is an important point, for it is very desirable to avoid the necessity for using animal or other external means of transport.

Fig. 66.—Electric Ploughing note the ropes attached to the plough Type 222.

Every farmer requires a vehicle for these purposes, and if he can use the same one for ploughing, cultivation, and transport, considerable capital outlay is saved. This is well worth while, even if the speed on the road is comparatively low.

The use of a half-creeper track will overcome the chief objection to the wheeled tractor, viz., the compression of the

soil due to its weight, for it becomes possible to reduce the pressure on the soil to less than that due to a man's weight.

This track may be compounded of rubber and fabric, or rubber tyred wheels may run on a metal track. If a metal track is employed, it should preferably be steerable so as not to skid over and damage the ground when turning a corner. The front wheels of the tractor should be fitted with extra large pneumatic tyres. With this arrangement the equipment will

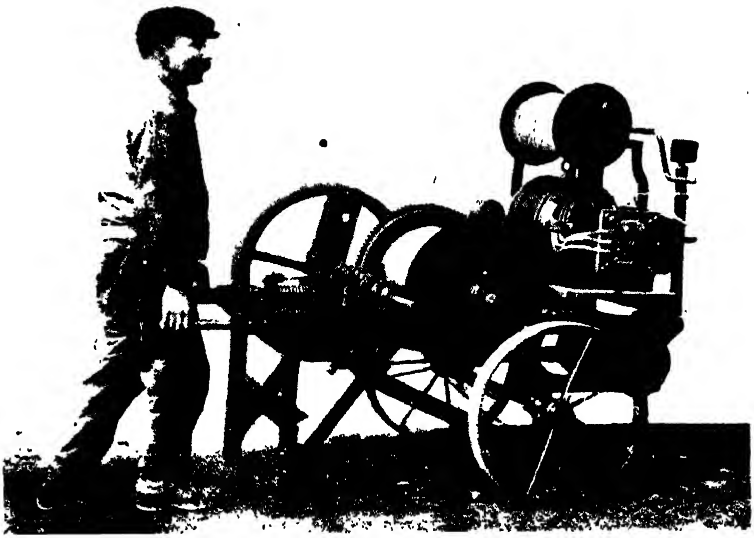


Fig. 67. A Vineyard and Market Garden Electric Plough.

be able to travel on the softest land, the pressure on the ground being reduced to about 10 lbs. per sq. in. (70 Kg. per sq. dm.). As an alternative, the possibilities of the coupled four-wheeled drive should not be overlooked. The main motor should be of about 25 horse power. Since the field supply will be alternating current, and an accumulator is also used, a special traction type series wound motor must be employed. A flexible cable will feed the tractor when within reach of an electric supply. A mast should be fitted to the tractor, so that the cable may

hang free in the air for a distance of 35 to 40 yards (30 to 35 m.); beyond this it can lie on the ground. The drum should hold 440 to 550 yards (400 to 500 m.) of cable. In combination with this, it would add to the life of the cable if an additional winding motor of about 2 horse power were fitted, having an automatic hysteresis control. In the case of tractors having a plough at each end, so that they can travel to and fro without turning, the tractor cable should be attached to a cable feeder waggon on wheels halfway along the furrow. From a drum on this waggon a second cable should run to the overhead line at the side of the field. Each time the tractor passes the waggon, it will push the latter back a distance equal to the width of the furrows being ploughed, at right angles to the direction of ploughing. Some of the second cable will thus be automatically wound up on its drum.

In this way all risk of the tractor running over the cable is obviated and the wear and tear is reduced to minimum, since it has only to lie on instead of being dragged over the ground.

No tractor embodying all these features is at present on the market, though as far as the cable handling is concerned, a combination of the Forssblad, type 124, and McDowall, type 125, systems would be most satisfactory.

A tractor of this type would plough from 40 to 60 acres (16 to 25 hectares) from a single contact in the middle of a field. In other words, continuous furrows of about ½ mile (800 m.) in length could be ploughed. If a greater area must be reached from one point, it is easy to add another length of cable. However, it is only on rare occasions that areas of more than 40 acres (16 hectares) and furrows more than ¼ mile (400 m.) long, have to be ploughed at one time. Again, it is easy to arrange for several feeding points if a farm is to be equipped for electric ploughing.

Such a tractor could also carry out a variety of other work, such as cultivating, harrowing, rolling, seed drilling, harvesting, etc. All standard implements, except harvesting machinery, could be used in the usual way. In the case of a reaper, this could only be moved up and down in a field returning light each time. Continuous cutting round the field is impossible

since the flexible cable of the tractor would always be twisted in one direction, but it would be easy to modify slightly a standard reaper so as to make it suitable for both right and left hand operation (i.e., to operate to and fro).

Rotary Tillers.

Though so far ploughing has been the accepted first operation of tillage, it certainly seems unsatisfactory when the desired end is considered—to leave the inverted soil light and aerated. For the earth is really wedged over, and the bottom of the furrow is subjected to a pressure, which tends to produce the "hard pan" to which so many farmers object.

There are now quite a number of machines in existence which attack the problem in an entirely different way. These are called rotary tillers. As long ago as 1850, Wren Hoskyns pointed out that it is unnatural to apply mechanical power to draw a cultivating tool in a straight line. The natural thing would be to use a revolving tool. Just as the milling machine has largely superseded the planing and shaping machines in engineering workshops, so it seems likely that the rotary tiller will eventually supersede the plough.

The effect of the process is to produce a seed-bed in one operation, instead of the conventional stages of ploughing, cultivating, harrowing and rolling, some of which are often repeated.

Practical farmers condemned the earlier designs of these machines, as they could only produce a fine tilth, which, with autumn cultivation was apt to pack too solidly after the first heavy rain. In later models, however, with an improved shape of tine and by removing alternate ones, it is possible to leave the soil in the form of clods, and so minimise this difficulty. Further, manure can be thoroughly mixed with the soil and the weeds either buried or thrown out at the back to be collected as required; this could not be accomplished by the earlier machines. The cultivating unit or miller consists of an axle carrying two sleeves, each of which is fitted with a number (usually ten) of specially shaped coiled springs. On the ends of these are fitted semi-circular tempered steel hooks, which are the actual cutting tools and are easily renewable. Owing to the springing, the hooks are not normally damaged by meet-

ing obstacles, such as roots and stones in the ground. The miller revolves at about 150 revolutions per minute. The principle is illustrated in Fig. 68.

As previously mentioned, any of the types of electrical equipment already described could be applied to rotary tillers. While the tractor principle is preferable, as the "miller" can have a direct drive from the motor, rope haulage could also be used, the "miller" being driven from the soil by bull or straked friction wheels.

The machines so far constructed are of a self-contained type, comprising the power unit and the cultivating unit. Three

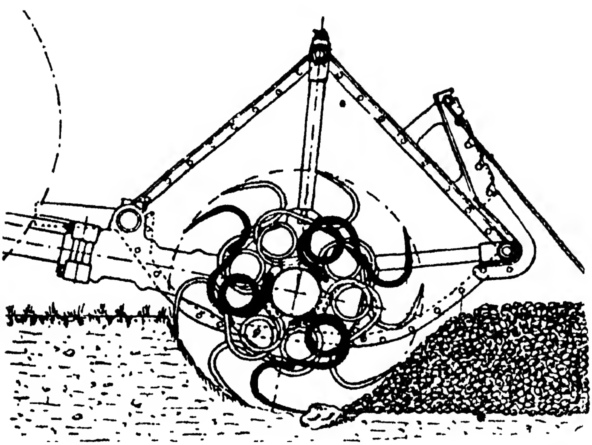


Fig. 68.—Diagram showing operation of Rotary Tillers.

sizes have been in use for several years, having 4, 10 and 30 horse power motors. A 50 horse power, petrol driven, rotary tiller, the Foote, was awarded a silver medal at the Royal Agricultural Show in 1926. With the 10 horse power size, the average width of work is 3 ft. (90 cm.) and the depth from 1 to 10 inches (2·5 to 25 cm.). The area covered varies from 0.2 to 0.5 acres (0.08 to 0.2 hectares) per hour, and the speed of travel is normally 1½ miles (2½ Km.) per hour, or ¾ mile (1.2 Km.) on low gear.

The 30 horse power size is designed for larger farm areas. It can deal with 0.5 to 1.5 acres (0.2 to 0.6 hectares) per hour,

the maximum depth being 14 inches (35 cm.). A recent development is the application of electric drive to this size.

The four horse power machine is very useful for the smaller user, as it can work well in gardens and in any confined space such as between rows of vines, or fruit trees and bushes. (Fig. 69). It has found favour for mountainside cultivation as is needed in Switzerland and elsewhere, since it can work on a slope of 1 in 5 without difficulty.

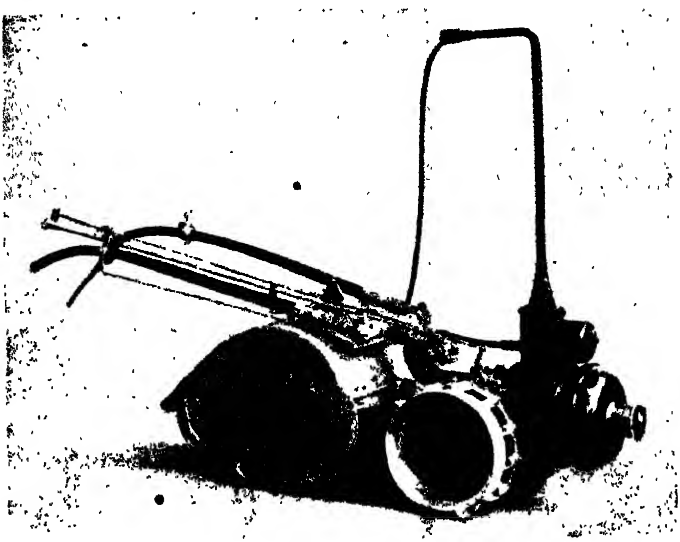


Fig. 69.—An electrically operated Rotary Tiller for Garden Work.

Costs of Ploughing.

Ploughing is looked upon by the layman as a strictly seasonal occupation. However, it is found in practice that an electric ploughing set can be kept fully occupied for at least 200 days in the year, quite a reasonable period over which to spread interest and depreciation.

The costs of any kind of mechanical ploughing are very elusive, as the companies and co-operative societies, who usually carry it out, base their contract prices on existing horse-ploughing competition, also taking into account the fact that at certain

times farmers are quite willing to pay a little above the horse rate if the work can be accomplished more quickly.

The contract prices collected in the report of the I.E.E. Electricity in Agriculture Committee,* form a useful comparison.

The following are British prices:—

Steam ploughing: 15/- to 25/- per acre, about 6 ins. deep.

Tractor ploughing: 17/6 to 30/- per acre, according to depth and nature of soil.

Horse ploughing: 20/- to 35/- per acre.

As there is no electric ploughing yet in progress to any extent in England, no figures can be given. The following figures are for French electric ploughing contracts in 1924, according to Hubert :—

Depth of				Total Depth.		Price per acre.	
Ploughing.		Subsoiling.					
in.	cm.	in.	cm.	in.	cm.	Francs.	s. d.
10-12	25-30	5-6	13-15	15-18	38-46	137	34 3
8-10	20-25	5-6	13-15	13-16	33-41	130	32 6
12-14	30-35			12-14	30-35	127	32 0
10-12	25-30			10-12	25-30	120	30 0
6-8	15-20	5-6	13-15	11-14	18-35	120	30 0
8-10	20-25			8-10	20-25	93	23 0
6-8	15-20			6-8	15-20	66	16 6

The conversion to English money is at the rate of 80 francs to the £, but the comparison must not be taken too literally, owing to the differences between the external and internal values of the franc.

At the same date, the charge for scuffling for a depth of about 4 inches was 40 francs (10/-) per acre. As an approximate rule, the charge for ploughing and sub-soiling was about 10 francs (2/6) per inch of total depth per acre.

* Journal British I.E.E. 1925, Vol. 63, page 840.

Any attempt to make an actual calculation of the cost of ploughing by different means, is apt to be unpractical owing to the assumptions which must be made. It is, however, interesting to compare the results thus obtained with the relative contract prices, for a tractor with an internal combustion engine, and a tractor with an electric motor.

Assumptions.

Consumption of electrical energy 22 units (kWh) per acre. This is a very usual figure for average depths and soils on the Continent, though it would be more like 15 units (kWh) in England. Efficiency of motor and transmission of electric tractor, 75 per cent.

Thermal efficiency of internal combustion engine 14 per cent.

Calorific Value, Specific Gravity and Price of fuels for engine as follows :—

	Calorific Value B.Th.U.per lb.	Specific Gravity.	Price per Gallon.
Petrol	19,900	0.7	1s. 2d.
Paraffin	18,900	0.8	$9\frac{1}{2}$d.
Fuel oil	18,000	0.9	$5\frac{1}{2}$d.

Allowance for lubricating oil :—

$3\frac{1}{2}$d. per acre with petrol.
$4\frac{1}{2}$d. ,, ,, ,, paraffin.
8d. ,, ,, ,, fuel oil.

Cost of electrical energy 0.85d., 1d., and 1.4d., per unit (kWh). Area ploughed in each case 5 acres per day. Cost of labour, engine driven tractor 8/6d. per day, electrically driven tractor 6/- per day.

The cost of labour for the engine driven tractor is estimated higher, since more skill is required for driving it and also fuel and water must be brought to it when in use.

Depreciation : Oil engine driven tractor with plough, first cost £475, replaced in five years.

Electric tractor with plough, but without cable, first cost £500, replaced in 15 years.

These relative times are not unreasonable, considering the well-known long life of an electric motor and the smooth drive which it gives.

Interest 6 per cent.

Work done per year, 200 days at 5 acres per day—1,000 acres.

Repairs and maintenance, engine driven tractor £40.

„ „ „ „ electric driven tractor £20.

Additional cost of depreciation on flexible cable for electric tractor £24 per annum, allowing for displacement in two years.

Cost per acre.

The 22 units (kWh) required by the electric tractor produced at the axle 0.75 × 22 × 3,400 = 56,000 British Thermal Units (B.Th.U.).

To produce the same amount of energy with the various fuels, the quantities required would be :—

PETROL : $$\frac{56,000}{0.14 \times 19,900} = 20.1 \text{ lbs.} = 2.9 \text{ gallons.}$$

PARAFFIN : $$\frac{56,000}{0.14 \times 18,900} = 21.2 \text{ lbs.} = 2.7 \text{ gallons.}$$

FUEL OIL : $$\frac{56,000}{0.14 \times 18,000} = 22.2 \text{ lbs.} = 2.5 \text{ gallons.}$$

Cost of	Engine driven tractor.		
	Petrol.	Paraffin.	Fuel Oil.
	s. d.	s. d.	s. d.
Fuel	3 5	2 2	1 2
Lubricating oil	3½	4½	8
Labour	1 8½	1 8½	1 8½
Repairs	9½	9½	9½
Depreciation	1 11	1 11	1 11
Interest	7	7	7
Total cost per acre	8 8½	7 6½	6 10

Cost of	Electric tractor.		
	0.85d. per unit (kWh)	1.0d. per unit (kWh)	1.4d. per unit (kWh)
	s. d.	s. d.	s. d.
Current	1 7	1 10	2 7
Labour	1 2½	1 2½	1 2½
Repairs	5	5	5
Cable	5½	5½	5½
Depreciation	8	8	8
Interest	7½	7½	7½
Total cost per acre	4 11½	5 2½	5 11½

To these, of course, must be added overhead charges of, say, 150 per cent., as is necessary in any business, to cover management, supervison, advertising, office expenses, etc.

The results given in the table show that even with electricity at 1.4d. per unit, electric ploughing is cheaper than ploughing with a tractor using fuel oil, while with paraffin and petrol the difference is still more marked.

The calculation does not take account of the fact that the work which can be done by an electric tractor is considerably greater for several reasons. Attendance takes up less time and stoppage for repairs are much less frequent, also all the trouble of purchase and transport of fuel, lubricating oil, water and spare parts is avoided.

It is interesting to compare these figures with the actual costs of steam ploughing, as shown by the books of a large ploughing contractor. These figures are the average costs per acre of 5 sets operating over a period of twelve months. The average acreage ploughed per day was 5½ acres.

Cost of	Steam Ploughing.
	s. d.
Fuel and oil	3½
Labour	6 8½
Repairs and maintenance	11½
Depreciation	1 3
Interest	9
Total cost per acre	9 11½

Advantages of Electric Ploughing.

Those who oppose electric, or indeed any other mechanical ploughing, generally say that the farmer must in any case have a number of horses or oxen for harvesting, hoeing and general cartage, so that he might as well use them for ploughing also. This argument would be sound if the ploughing could be spread over a long period, and done a little at a time when the animals were not otherwise employed. In practice, however, it is advisable to get the main ploughing practically completed as early as possible in the autumn. Of course, for autumn sown crops, early ploughing is essential. It is, however, interesting to note that in Canada, even for spring wheat, it is usually considered best to plough in the autumn, particularly on heavy, wet land. In England, bad weather often causes delay in getting on the land, on this account when a favourable opportunity occurs, something quicker than horse ploughing is of great utility. This is supplied by electric ploughing.

The advantages of electric ploughing may be summarised thus :—

1. Practically unlimited power is available behind the plough. Thus any obstruction within the capacity of the plough can be broken up ; to prevent damaging the plough on a very severe obstruction, a safety device in the form of either a coupling pin which will shear, or a slipping clutch is fitted.

Again, very deep ploughing becomes possible, such as 18 inches (46 cm.) with 6 inches (15 cm.) sub-soiling. This is very important, particularly for sugar-beet growing.

2. The cost per acre for electric power is considerably lower than for any fuel.

3. Saving in labour. The work of transporting fuel and water is entirely eliminated. Three men or in some cases two men are sufficient to work the apparatus, which can plough a much greater area per day than other methods.

4. Increase in acreage available for producing income. Professor Fletcher of the University of California has calculated that on an average 24 per cent. of the wheat, 67 per cent. of the oats, and 44 per cent. of the hay, produced on a farm, are used for feeding the working animals. If electric power is used all this produce is available for sale.

5. Advantage can be taken of favourable weather to get the whole area ploughed quickly.

6. In addition it is possible, where unavoidable, to carry out ploughing in weather when horses could not go on the land at all.

7. Great regularity in the ploughing, giving a flat surface on which water will distribute itself evenly.

8. In the case of cable systems the haulages do not traverse the main portion of the land ploughed, which remains light and aerated.

9. Electric ploughing is of great importance in the development of the rural distribution system, and should therefore be encouraged by all engineers interested in rural electrification. It provides, if combined with scuffling and threshing, a steady load for some 200 days, right through the autumn, winter and early spring. The amount of this load averages two or three times that obtained from other sources, so that it is the mainstay of profitable rural electric supply.

Conclusion.

Up to the present, the greatest progress in electric ploughing has been made in Continental countries, such as in France, Germany, Scandinavia, Italy and Russia. The first equipment used in England was on the farm of Mr. Chorlton, at Cotgrave, Nottinghamshire. It was on the double-winder rope system, and was started up in 1910. The second equipment to be put into

operation was that on the author's farm, which is on the Douilhet round-about system. The third equipment in Great Britain—to be precise in Scotland—is that of Major A. McDowall.

Successful electric ploughing tackle on a variety of different principles, has been working in various parts of Europe for a number of years. In point of fact, over 200 electric ploughs are now in existence.

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CHAPTER X.

HARVESTING.

Decimal Class. 631.55E

TABLE XV.

USES OF ELECTRICITY.

Fans.
Heaters.
Elevators.
Conveyors.
Chaffing Machines.
Disintegrating mills.
Pulping machines.
Reaping machines.
Combined reaping and threshing machines.

Making Hay without Sunshine.

Normally, given suitable weather conditions, the ordinary way of making hay by aid of the sun is quite satisfactory. However, in bad weather, artificial haymaking becomes a most attractive proposition. A rainy period at hay time sends up prices with a rush. This is on account of the fear that hay will be short and poor. So the farmer, who can supply the demand as it arises, can obtain high prices. Hence artificial drying or conditioning or curing, is worthy of interest, and all preparations should be made for carrying it out in wet seasons. It even has advantages in average seasons, for the hay can be made to a given standard of quality, with less labour. In making hay, about sixty per cent. of the growing weight of the grass has to be evaporated. In the case of the artificial method, this in itself is no light task, apart from the fact that most of

this excess moisture has to be carted to the place where the crop is to be treated. However, it is well known that rain-washed hay loses its most valuable constituents, the water soluables. Also over-ripe hay, due to delay in cutting, is rank and of little value as food. Hence the importance of an improved method of haymaking.

In many parts of England, adverse weather conditions occur at haymaking time at least once in every five years, while in Scotland and on the West Coast of Ireland the weather is a "wee bit saft" nearly every year. Again, where the land is cold, the hay crop is often delayed, and is apt to get caught by the early July rains. Thus any methods for making hay which are independent of the weather merit very careful consideration. The question is not a new one. The Swiss, Swedes and Germans, have expended thousands of pounds in vain attempts to make hay artificially. Experimental work to the same end has also been carried out by enterprising farmers in various parts of Great Britain for a period extending over 75 years—again without satisfactory results. The very bad season of 1879 gave new life to the experimenters of that period and a great deal was done the following season. Appliances were brought out, which claimed to dry the hay either in the field or farm yard. The idea underlying these experiments was that if only the heated gases from the interior of the rick were removed, the cool air from the outside would rush in and in this way do away with all the troubles associated with the heating of grass stacked in a damp condition. But the results were as unsatisfactory as the previous ones.

Some years ago (in 1918), the author commenced experimenting with small samples of grass with a view to ascertaining whether or not the early difficulties could not be overcome. As an outcome of this early experimental work, he was invited, as was also Mr. A. Boyd, the Ventilating Engineer, by the late Mr. W. W. Hood, the well-known mining engineer, in 1920, to take part in what turned out to be a successful experiment in artificial haymaking. This test was carried out in Scotland, where haymaking conditions may be said to be nearly always unfavourable. The type of rick employed was the standard

cock of the district, of about five tons, built on the usual local, equilateral, triangular pole support. The grass was cut green from a marshy meadow with the rain on it and immediately stacked. A wooden duct was led into the base of the stack with an outlet under the supporting structure. Air was blown through this duct, by means of an electrically driven plenum fan, which absorbed 3.25 horse power and produced a pressure of 2½ inches on the water gauge.

It was found that the rate of drying was in direct proportion to the amount of moisture suspended in the atmosphere. No drying took place when the atmosphere was saturated, though the passage of the air through the stack prevented the rick from over-heating. The rate of evaporation was found out to be at the rate of 2 oz. per 1,000 cubic feet of air per degree Fahrenheit (63 gm. per cubic metre of air per degree Centigrade).

During this test, as one of the experiments, smoke was introduced to the stack through the fan intake. It was very interesting to note the uniform manner in which this smoke appeared all over the stack, which greatly relieved the minds of the experimenters. This demonstrated the effectiveness of the primitive form of duct employed, and showed that very simple apparatus is required for this process of haymaking.

Owing to the prevailing rain and mist, the rick only actually dried when the air was not fully saturated. Hence the making of the hay in this instance occupied some thirty hours. Altogether the experiment was so promising that it justified a scheme for dealing with the English type of rick, containing about 25 to 40 tons. The author was the first to make a successful full sized rick in this manner, and soon afterwards a similar stack was constructed near Chepstow under the supervision of Mr. Hood. The fans required for these ricks only consumed five horse power.

It is rather extraordinary, but very little scientific work had been carried out to investigate what really occurred in the process of haymaking. Hence very little data was available to facilitate the author's work. As a result of the experiments conducted by him, he came to the conclusion that hay has to be cured and not merely dried. The engineers of the Ministry

of Agriculture and Oxford Engineering Institute consider that it is sufficient to dry the material. However, livestock seem to prefer the cured hay to ordinary hay, and further, forage merchants give a higher price for the cured material simply on the basis of inspection and test.

In the first stage of this curing, heating occurs due to the respiratory activity of the plant cells. During this period the hay sweats and reaches a temperature of about 122 deg. Fahr. (50 deg. Cent.). Then further heating occurs, attributed by various authorities to bacterial action, ferment activity and the catalytic action of combinations of iron and manganese. These actions result in an increase of temperature to about 158 deg. Fahr. (70 deg. Cent.).

A good deal of vapour is given off, together with an aromatic smell, and the hay turns a light brown colour. If not controlled properly, the stack heats further and chemical changes take place, which, if not arrested, say by the aid of a fan, eventually destroy the nutritive value of the hay, even if the stack is not set on fire.

The modern processes of artificial haymaking have been developed by engineers with farming and ventilating engineering experience. Probably this, coupled with the fact that better appliances are available to-day than there were forty years ago, accounts for the greater success attained by present day experimenters.

Modern methods may be approximately classified as follows:—

Methods of carrying out operation.

Fixed fan installation.
Portable fan installation.
Continuous conveyor system.
In a vehicle.

Different Methods of Treating the Hay.

Curing (without internal structures):
with (a) Cold air, i.e., at temperature of atmosphere.
(b) Hot air, above 180 deg. Fahr. (82 deg. Cent.).

Drying (with internal structures):
with (a) Cold air, i.e., at ordinary temperature.
(b) Warm air up to 180 deg. Fahr. (82 deg. Cent.).
(c) Hot air, above 180 deg. Fahr. (82 deg. Cent.).

The Curing Process (without internal structures).

The aim of the author's later work has been to obtain properly cured hay by a method which would permit of the treatment of large stacks (of the sizes usually constructed by most farmers), either in the field or under a Dutch barn, and he has successfully treated stacks of from 15 to 60 tons, producing excellent hay, as distinguished from merely dried grass, as the latter has not the same fodder value for animals. While the author's first ricks were far from perfect—as might have been anticipated—all the hay he has produced artificially has been

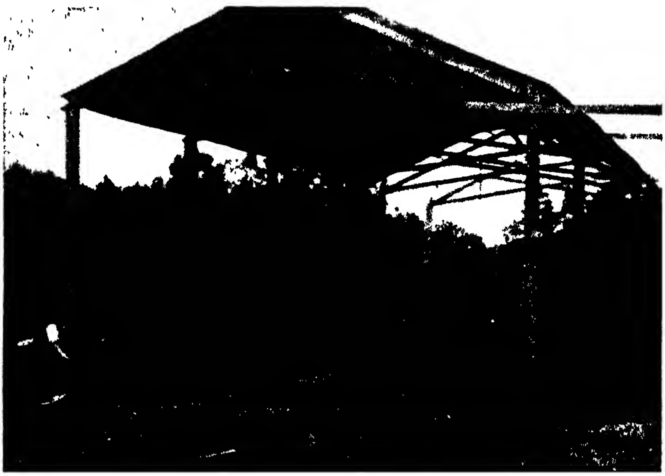

Fig. 70.—Preparing the ducts.

consumed with avidity by cattle. This is obtained by temperature control, which allows certain bacteriological and chemical changes to take place, and at the correct point the processes are arrested, with the result that a sweet-smelling hay is obtained of good food value and all harmful fermenting is avoided. The process is essentially of a very simple character and can be carried out, without danger, with very little instruction. There is no need to make wooden frames upon which to build the rick. On the place where the ricks are to be built, ducts or covered channels are constructed about ten feet apart, with

openings at about every ten feet of their length. Instead of making these ducts of wood, asbestos-cement, concrete or sheet metal, they can be very simply constructed as is shown in Fig. 70, by cutting a trench in the ground and covering this with pieces of wood ; the earth that has been removed in cutting the trench can be placed on top of the wood so as to keep the

Fig. 71.—Construction of duct.

duct air-tight. (Fig. 71). Air tightness is also facilitated by putting a sheet of ruberoid over the wood and throwing the earth on the top of that. On the left-hand side of Fig. 72, near the man's foot, will be seen one of the openings covered with wire netting. It will be observed that high-sided extensions are provided so as to give the air a lead into the cavities

above. The next step, before commencing to build the rick, is to place over each opening a drum or former; the object of these drums is to make vertical cavities or closed shafts within the rick. The rick is built in the ordinary way and when it comes up to the level of the top of the drums, the drums are pulled upwards in the same way as the old-established practice of drawing a bag of hay up a rick of straw when making a ventilating chimney. When making hay in the modern way, however, the former is removed when the cavity has reached about two-

Fig. 72.—Putting the formers into position over the ventilators in the ducts.

thirds of the height of the finished stack. Some pieces of wood or a trellis are then thrown across the cavity, to prevent fresh material from falling down and filling it up and the rick is completed in the usual way. The object of these vertical cavities is for the purpose of distributing the air equally from the ducts. (Fig. 73). The main ducts in the ground under the ricks are led to a portable fan. This can be operated by an oil engine, a tractor or an electric motor—the latter is, of course, the most convenient and cheapest method where electricity is available. (Fig. 74). It is advisable to run the fan for at least an hour

within the first twenty hours from the time stacking is commenced. If the grass or sheaves are very wet with rain, blowing must be commenced immediately the stack is completed and continued for 10 to 15 hours ; this allows the air an easy passage as the stack will not have consolidated and the surface moisture is more easily removed and all danger of mould eliminated. Temperature readings are then taken twice a day and it is usually found that blowing is necessary for about half-an-hour to an hour every day for ten days, to keep the temperature within

Fig. 73.—A cross section of the finished stack showing one of the vertical cavities.

proper limits. Three or four thermometers which are enclosed in steel tubes are pushed into the stack for a distance of 3½ feet at heights of 5 to 16 feet above the ground. They are adjusted for reading at any point within the rick by means of a length of wiré projecting from the top. The size of fan required for a stack of from 25 to 100 tons is one that will absorb the full power of a five horse power electric motor or of a 7½ horse power oil engine. It is better to err on the right side and get a fan that is too large, rather than one that is too small. The

existence of a fan in a stack yard is better than a fire insurance policy, as if the ricks are constructed with ducts in the manner described above, even though the hay is made in the ordinary way, any tendency to heating can be controlled by the fan. Four years out of five, better hay can be made by the improved process than by the ordinary method, that is, though better hay may be made in the ordinary way, one year in five, the farmer who is working the new process is assured of a hay of uniform quality every year whatever the weather may be. Hay made in this

Fig. 74.—Testing the temperature of the stack. (Note portable motor.)

way is more closely packed in the rick than ordinary hay, thus facilitating cutting and baling. As there is no need to toss the hay in the field the clover and other similar herbage is all conserved in the rick. In the ordinary way a great deal of this is lost in the tossing and carrying, as it becomes brittle, falls to the ground and is left in the field.

Artificially cured hay looks better, and has a better aroma than naturally dried hay (except in about one year out of five). Also the food or nutritive value is greater. Incidentally, when

artificial curing is adopted, the process can be made a continuous one, and not hurriedly accomplished with a large amount of special labour, as is usually the case with what may be termed natural or semi-dried hay. The author's practice in favourable weather is to cut in the morning and with the aid of the same men stack in the afternoon.

The results obtained should go far to revolutionise haymaking and save the farmer very considerable sums of money. The following table, based on an analysis of haymaking costs in 1921 for average crop and weather conditions, shows how large the saving becomes. Since then, costs have been reduced, however the proportions naturally remain the same.

TABLE XVI.

ANALYSIS OF HAYMAKING COSTS IN 1921 FOR AVERAGE CROP AND WEATHER CONDITIONS.

	Sun-made hay.	Electric fan-made hay.
	£ s. d.	£ s. d.
Cutting	10 0	10 0
Turning (twice)	6 0	nil
Raking (once)	3 0	nil
Windrowing	3 0	3 0
Carting and Stacking	18 0	18 0
Cost of electric power	nil	1 3
Interest and depreciation of blowing plant at a cost of £60	nil	1 0
Total cost per acre	£2 0 0	£1 13 3

In making comparisons between the cost of the two systems it must not be forgotten that the present method of cutting and carting can be simplified and changed where field drying is not required. This will reduce the cost of fan-made hay still further.

Having dealt with the practical features of the system, it may now be well to consider the underlying principles.

In the process and by means of the devices employed in the carrying out of the author's method, the final conditioning of the hay or cereal crops is achieved by natural bacteriological and chemical actions, and the blowing of preheated or ordinary air through the ducts or passages constructed under, through, or in the stack, is employed to check or control such actions when they have progressed sufficiently and to distribute the heat which has been generated in lower portions of the rick due to such actions which are normally more active where the consolidation of the mass is greatest. The effect is to cause similar actions to commence in adjacent higher and less consolidated portions of the stack at an earlier period than would normally be the case. Owing to the pressure of the material in the rick, the actions referred to above commence at the bottom of, and also in the centre of the rick, and work progressively upwards in accordance with the control by blowing air through the rick as required, to approximate that temperature which experience has shown to be most desirable. This temperature varies for hay from 80 to 160 deg. Fahr. (27 to 71 deg. Cent.) in accordance as to whether a green (for cattle) or a brown (for horses) hay is desired or some intermediate colour by aid of an intermediate temperature. For unthreshed cereal crops, a suitable temperature is in the neighbourhood of 80 to 120 deg. Fahr. (27 to 49 deg. Cent.). In previous attempts and methods of drying or curing hay or cereals in the stack, frames or racks have been used around and over which the grass or sheaves have been stacked forming vertical channels through which air is forced. This method has been found in practice to be inefficient and to result in a product of un-uniform quality and appearance. This is due to the fact that the green material shrinks in height with the result that the upper parts of the rick resting upon or retained by the framework, cause layers of lower air resistance through which an excessive amount of air is passed, thus short circuiting the denser and hotter portions through which the air blast is most desirable.

Now the author's system is based upon attaining equal air resistance at all parts of the stack and enable this equivalent resistance to be approximately maintained throughout the con-

ditioning process. By so avoiding short circuiting of the air, uneven bacterial action, chemical action, heating and therefore inequalities in the product are obviated.

Another advantage gained by this method is the ease with which rectangular stacks of any size can be built and handled. It is advisable that the building of the material about any central shaft, should be completed within a working day, in order that uniform results may be obtained throughout the mass, with less intelligent control. By this method, it is possible by suitably choosing the shaft spacings, to build a large rick in convenient stages, so that one end of such a stack may be cured hay, before the grass has been stacked at the other end. It is possible to do this by providing suitably vertical ducts or air shafts of suitable size and running from top to bottom of the ricks, to carry off the moisture, air, etc., blown out from the neighbouring air shafts.

In order to prevent air leakage between the newly built parts of a large rick and those already in the process of curing, suitable keying sections in place of straight line or plane surfaces are made use of, which may be formed by ordinary building or by the use of temporary external wooden or metal frame works which are placed in position whilst the section is being built. The section so built, forms a bond into or against which a new section may be built in like manner, so that air will tend to be distributed by means of the vertical shafts provided, in the same manner as if the rick were constructed as a complete rick in one stage.

In order to prevent loss of air through inlet bases not yet covered, or to cut off the air supply to sections in which blowing is no longer desired, a system of valves or flap doors which may be closed manually by crawling through the ducts or by any convenient external means, is employed, or by electrical or pneumatic or other method of remote control, as by means of a bye-pass operated air valve and other equivalent devices.

It sometimes happens, as for instance in stacking under a Dutch barn, that the available height is not sufficiently occupied after shrinkage has taken place, due to the loss of volume consequent on curing (roughly 50 per cent,). In such cases

further material may be built over the conditioned material, by first removing or flattening the original ridge and then cutting by any suitable rick ventilating tool a vertical duct to communicate with the duct formed when building the lower part of the rick. The process can then be repeated and in such a manner the maximum height of the barn can be utilised.

Alternatively the former may be allowed to remain in the partly built rick and will then serve to close the shaft temporarily while treatment is proceeding. In this way, more material can be conveniently added to the rick as shrinkage takes place.

If the hay drying apparatus be combined with auxiliary arrangements, for drying fruit, vegetables, hops, etc., it becomes a paying proposition for any farm, even when it is not used for hay drying in favourable sunny seasons. In fact, the electric motor can be detached and employed on other work during most of the year.

It must be remembered that as hay is a bulky and cheap substance, the cost of handling must be reduced to a minimum. In fact, in Germany, artificial hay drying has been commercially unsuccessful in many parts, owing to close ahderence to vegetable drying methods which involve double transport, and much handling. While the process was not developed with the idea of saving labour in the field, in practice it does so, for the trouble of turning and often the necessity for cocking is eliminated. Against this saving has to be set the cost of running the fan, which however is only a little over a shilling a ton. As the grass is carried in a green state, the weight to be transported is greater; on the other hand, less labour is required to pack it on the hay carts and also in stacking it. Further, it will be appreciated that a load of hay really represents only a fraction of the pulling capacity of a tractor or a team of horses, for it is so bulky compared with its weight.

While the instructions for this process, as will have been gathered from the above description, are very simple, it will be appreciated that the dimensions given for one size of rick, will not necessarily serve for another. The reason for this is that the whole process depends upon ventilating engineering principles and the resistance to the passage of the air must be

equal in every direction, or else the rick will not be under proper control. The whole thing looks so simple, that one is apt to think at first sight that there is nothing more in it than that of driving air into a stack. Several farmers, who were enterprising enough to try out the system upon the basis of what they had seen or read about it, have been unsuccessful. This might have been anticipated, for if the process were as easy as it looks, it would have been done many years ago.

Fixed Fan Installation.

Unknown to Mr. Hood and the author, Mr. Charley Tinker had previously made dried hay artificially on a large scale, by a different process. This particular method, however, involved treatment of the hay in comparatively small lots, which had to be removed when dried and stacked elsewhere, so that the somewhat expensive installation could justify itself by being used for further crops. However, it is doubtful whether it pays to do much handling on such a cheap crop as hay. Mr. Tinker's process, in the author's opinion, is essentially one of drying by subjecting the crop to an excess of air, and not of curing.

Portable Fan Installations. Drying with internal structures. Cold and Warm Air Processes.

The author having satisfied himself by further full scale tests, on a modified basis, that artificial haymaking was a process that could be carried out by any farmer, the Ministry of Agriculture was approached with the suggestion that corroborative tests should be made. Through the courtesy of Sir Daniel Hall, the Ministry agreed to do this, so officials visited the author's farm to inspect the ricks built there, and they also went to see the rick built at Chepstow under the supervision of the late Mr. Hood. They subsequently carried out a number of full size experiments in 1924. Unfortunately, these experiments were not as successful as they might have been, as it was decided by those in charge of the tests, to explore some of the work of the earlier experimenters, instead of taking full advantage of the experience of Mr. Hood and that of the author. During the winter 1923-4 the Ministry conducted some most useful,

valuable and painstaking laboratory research, which added much to the scientific knowledge of the subject. During the progress of this work, the technical staff of the Ministry of Agriculture was transferred to the Institute of Agricultural Engineering at the University of Oxford. This time they reverted to preheating of the air, at various temperatures up to 180 deg. Fahr. (82 deg. Cent.) which had been tried and given up as unnecessary by the author for ordinary hay, though it has advantages for leguminous crops such as clover or hay made of fleshy marsh plants where there is excessive moisture. The apparatus, which

Fig. 75.—Drying plant used by the engineers of the Ministry of Agriculture and Oxford Engineering Institute.

has recently received so much publicity in the press, has now been put on the market by a private company. (Fig. 75). It consists of an oil fired preheater (as an alternative to the electric, wood and coke preheaters previously used by the author and his friends), a fan, a canvas duct, a metal duct and a central wood frame chamber. The latter was adopted from Mr. Tinker's work. These central chambers are a serious drawback, as their presence makes it difficult to cut the stack for trussing. The plant can be operated by a tractor or farm engine or electric motor of about 20 horse power. The heater is constructed so

that paraffin or fuel oil burners are used to heat two S shaped tubes arranged horizontally. The tubes are made of sheet metal with firebrick linings.

The air is drawn by the fan across the heated tubes and so becomes warmed. The warmed air is then driven into the stack by way of the canvas duct and metal inlet duct. The canvas duct connects the outlet of the fan to the metal inlet duct, and may either rest on the ground or else be sunk in, so that the air is directed upwards. The latter method has proved more satisfactory. The diameter of the duct near the central chamber is larger than it is near the fan so as to allow the stream of warm air to be distributed more regularly throughout the stack, by avoiding the disturbing effect of turbulence. Wood battens, covered with wire netting and made in a conical shape, are used to form the central chamber. There are two designs of the central chamber, both of which are due to Mr. Charley Tinker. The first is a simple form with no dampers. Where this one is employed, the whole stack must be built before blowing commences. The second type, is provided with dampers, so that blowing may commence when the stack is about 3 or 4 feet above the first damper. The number of stacks cured in this way, though they have not been as successful as their promotors expected, have at least substantiated the success of what might be termed the modern school of haymaking by artificial methods, as developed by the author and his friends. Unfortunately, a great deal of money has been rather uselessly expended on the official tests of this method (in the early stages this amounted to £8,000 ; the actual figure to date, given to the author in confidence has amounted to very considerably more than this). Most of this expenditure might have been saved, if only advantage had been taken of the freely proffered advice of the private investigators and much better results would have been obtained, as even now, only small stacks can be dealt with in this way, of which only about fifty per cent. have been really successful and these probably only because the hay was allowed to be on the field one or two days before stacking. The Ministry have, however, recently published the results of their tests and have now acknowledged (which is some-

thing that they were not inclined to do before) the previous work of the modern experimenters, whose work is referred to in this chapter.

Hot Air Process.

During 1926, the Ministry designed a new plant which was in effect a hot air process, using a temperature of over 180 deg. Fahr. The apparatus employed is considerably larger than that used in the past. It is approximately nine feet high, five feet wide and ten feet long and weighs about 2¼ tons. (Fig. 76).

Fig. 76.—New portable hot air apparatus in operation.

The general principle of design is similar to that of the earlier models, except that improved burners are substituted which consume a cheap fuel oil. Tests have shown that the consumption of oil is about one gallon per hour and it is stated that this oil can be purchased for 4½d. per gallon. There is still one serious drawback to this system; the ricks that are made are of a size more in keeping with Scotch practice and are probably far too small to please most English farmers. However, this plant has shown that a high temperature (over 180 deg. Fahr. or 82 deg. Cent.) eventually produces certain satisfactory results and has opened out an entirely new field.

Continuous Conveyor Drying Process.

A conveyor belt continuous drying process has been recently developed by Mr. Arthur J. Mason, a leading American engineer. During 1926, the first commercial plant of this type was installed at Plainsboro', New Jersey, U.S.A. The method of proceedure with this system is as follows :—

A modified reaping machine is drawn by a tractor and cuts the crop up into lengths not exceeding nine inches and delivers it automatically into a lorry running alongside it, which has a steel body about eight feet wide. When the lorry is full, it is taken away to the drying plant and another takes its place alongside the harvester. When the lorry arrives at the drying plant, the crop is tipped on to an elevator which is operated by a ten horse power electric motor and carries the crop to a height of about twenty feet. The crop then passes through spiked rollers or beaters where it is combed and prepared into an endless mattress of uniform texture eight feet wide and ten inches thick.

This mattress is then delivered by a chute on to a horizontal conveyor of about 160 feet long, which is driven by a ten horse power motor and travels at a speed of about five feet per minute. This conveyor then passes through a drying tunnel, which is about eight feet high and made of corrugated, curved galvanised sheets. Heated air, at a temperature of from 250 to 270 deg. Fahr. (121 to 132 deg. Cent.) and for non-leguminous crops up to 400 deg. Fahr. (187 deg. Cent.) is blown in at one end of the tunnel and passes over the top of the crop. An 80,000 cu. ft. fan driven by a thirty horse power motor is used for this work. The air is heated directly by passing through an anthracite coal fire, and as this coal is free of smoke and sulphur fumes, it does not have any deleterious effect on the crop. The air enters at the finishing end of the tunnel and passes over the top of the crop, down through it and then along underneath it. At the centre, there is a floating door which causes the air to rise through the crop again, whence it passes into the atmosphere in a saturated state through a vertical stack.

When the crop has passed through the drying chambers it is conveyed to chaffing machines and is there bagged or baled

immediately. A fifteen horse-power motor is required for this operation. When a lucerne crop has been treated, it is usually reduced to a powder in a disintegrating mill which is operated by a forty horse-power motor. This machine includes a fan for blowing the finished product through a delivery pipe. These pipes are run in to a barn which is equipped with storage bins and sack fillers. With this system, it is claimed that a crop growing in the field can be converted into hay and baled ready for transporting in forty minutes and the whole operation can take place without the crop being handled by a single individual. The plant will cure and bale twenty tons of hay in ten hours and the labour required is one man for mowing, three men for hauling and four men at the plant. The amount of coal used is about 8½ tons per day. The cost of this plant, including machinery, tractors, motors and storage plant is about £4,500, which at first sight appears to be a high figure. However, it should be borne in mind that eight men working on 600 acres of land can operate a plant of this type for 165 days of the year and deal with over £12,000 worth of products. This is therefore, in principle, a most important advance in economical farming methods.

The colour of the hay produced in this way is green, and it is claimed that this is good evidence of its digestibility.

Hay Drying in a Vehicle.

On the Continent, F. Ringwald has successfully dried hay in the waggons, before transport from the field to the barns (where the hay is stored in Switzerland). For this purpose a duct, provided with vertical, galvanised sheet metal standpipes, is placed ready in the bottom of the cart before loading it. When loaded, the cart is taken to a fan installation and backed on to it, so that the outlet of the fan can be connected to the duct on the hay waggon and air blown through the load.

Curing of Corn.

The curing method that has been employed for hay has also proved very satisfactory for the curing of corn. The corn is cured in a similar fashion. It is stacked immediately after cutting and the necessity of stooking, with its attendant losses, owing to birds, vermin, and the weather, is avoided. Further

there is no loss of grain owing to the shaking during handling, a loss which is considerable with the usual method in wet weather, as the stooks of ripe grain have to be turned a number of times to dry them. Further losses are also experienced by the grain sprouting and, in the case of barley, becoming bleached and so losing its value for malting. For leguminous crops the system is exceptionally valuable, peas, for instance, are a particularly risky crop under ordinary conditions, but the new method eliminates the risk entirely and produces an excellent green sample. The field is also cleared immediately, so that ploughing can be proceeded with much earlier than is the case with the old method. Since cultivation can be proceeded with so promptly an earlier and greater yield of the succeeding crop can be obtained.

Hard grain is immediately obtained, so that threshing and grinding can be done many months before the usual time. In fact, an excellent milling wheat is produced. This gives the farmer an opportunity of marketing his produce when prices are good. The straw obtained also has a higher feeding value.

The method is excellent for treating oats, for there is a good deal of green stuff on these when cut. For this reason, normally, if stacked too early, they tend to overheat. However, under the modern process, they get just the conditioning they require in the rick, which results in the production of an excellent looking oat.

All farmers know the defects of heating grain crops in the rick. In fact, some are perturbed by the temperatures recommended for the artificial process—or perhaps it might be better expressed as the controlled process. Now the temperatures are only those at given points and are not the true temperature of the whole rick. Hence the crops are not really overheated, in fact, this danger is entirely obviated. The author has treated ricks of corn as large as 200 tons by this method.

The whole process is sometimes described by critics as a "cold air" one. However, the foregoing description will have shown that this is not so.

The Pulping of Green Crops.

An entirely new process has been developed in Hungary, whereby green crops are chaffed and crushed to a fine pulp in

a mill. The object of this is to break down the walls of the cells of the plants and so permit the contents to be exposed to the digestive juices of the animal that consumes the product. It often occurs that much food value is lost because animals cannot break down the majority of the cell structures. This prepared pulp can be fed direct to the animal, or dried off with wheat offals or anything similar and then stored indefinitely.

Here again we see a new farm process which calls for the use of electric power and also improves the methods of agriculture, for crops can be cut continuously throughout the growing season, as fast as they get to the milk stage. It is, as yet, a new process and probably a great deal more experience is required. The size of motor required for driving this pulper is five horse-power.

Electrical operation of harvesting machinery.

The usual principle of operation of a binder for reaping grain crops, is by the traction drive of a large straked wheel (known as the bull wheel), which is the principal support of the machine.

This is quite a satisfactory method for ordinary speeds, under normal conditions, but the increased cost of labour and the greater value of time now-a-days call for faster cutting and also the possibility of cutting any kind of crop in any sort of condition by machine. Large crops are sometimes knocked about by rain and storm, and have to be harvested by the old-fashioned hand sickle, as it is impossible to tackle it with the machine, in fact, even the hand scythe cannot be employed in many places.

The use of an electric motor drive for the binder (as developed by the author) entirely overcomes the difficulties mentioned above, and tests on binders show that the draft of the binder is lessened. As the drive is not obtained from the bull wheel, the machine can be used in certain sections of the field, where wet ground has hitherto made the operation of the binder very difficult. The use of the electric motor also permits of the cutting of heavy grain in a proper workmanlike way, when the binder has to be drawn at comparatively low speeds, e.g.,

turning corners and the like. This is accomplished, owing to the fact that the knives or sections run at a constant speed throughout. It is this fact, coupled with the possibility of the independent control of the speed of the knives, that makes it practicable to cut heavy tangled crops, that have been blown about by the winds. Careful tests made by the Ministry of Agriculture show that to obtain the best results in cutting, a certain speed of the cutters must be maintained. This is only possible with an electrically operated machine. In practice,

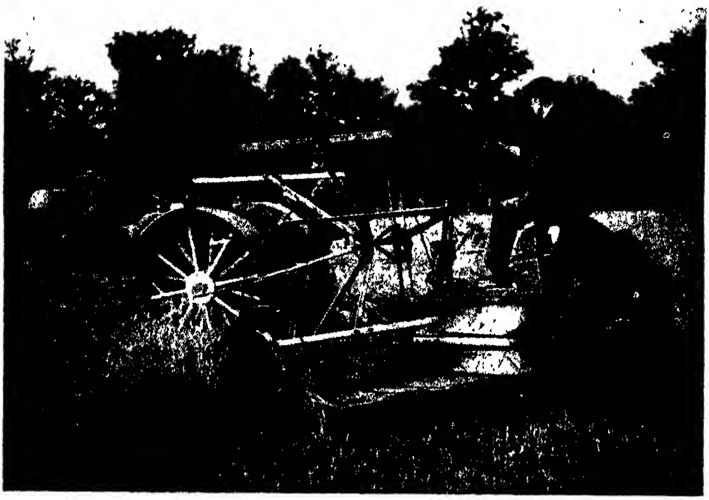

Fig. 77.—Tractor and electrically operated harvester. (Note controller near seat of driver.)

it is found that the use of electrically operated binders, effects a considerable increase in the acres cut per day, which as a minimum may be anticipated to be at least eight more than the normal sixteen acres. With the electric motor drive, crops can be cut at a rate which is about one-third faster than the normal. It also cuts the straw closer to the ground, thereby giving the maximum benefit from the crop, which is an important consideration when the straw is short and is of any value. The electric power for the driving motor is obtained from a

dynamo mounted on the tractor which is hauling the binders (one to three binders are often towed by a single tractor). (Fig. 77). The electric motor is of the variable speed type, with a controller fitted in a convenient position adjacent to the seat of the driver and the binder. The requirements of this special motor are. that it can be run at a practically constant speed, whatever the speed of the tractor. Similar beneficial results are to be obtained, when mowing machines are electrically equipped for cutting grass for hay.

In America, combined harvesting and threshing machines are successfully employed in certain parts of the country. This saves considerable time and is generally a great convenience. In addition the system circumvents bad weather conditions, which so often spoil a crop after cutting. In Great Britain, this practice cannot be followed at present, owing to the necessity for curing the grain, as it is not subjected to such powerful sunshine whilst growing, as in many other countries. The author is however of the opinion that it can be accomplished if proper heating and drying arrangements are provided at the farm buildings for the grain, as soon as it is carted from the field. He has, therefore, under consideration some tests to this end.

Obviously, a combined harvester and thresher is essentially a machine, where electric driving would be paramount.

Where soiling crops are fed to cattle in the byres, a harvesting machine, modified so as to handle green grass, can be usefully employed. In addition there should be incorporated a loading elevator, so that the crop can be delivered into an independent lorry running alongside. Mr. A. F. Mason employs such a machine, with the addition also of a chopper, for gathering his green crops ready for artificial drying by aid of his plant. Such special harvesting machines can very advantageously be electrically driven.

Where a farm is equipped with an electric ploughing set, or can hire the same from a co-operative society or contractor, it is of considerable economy to utilise the same equipment for harvesting. In that case the standard harvester will have to be run idle one way. It should not, however, be a difficult matter to make these machines double acting, and thus save much time.

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CHAPTER XI.

HANDLING CROPS.

Decimal Class. 631.56E

Fodder is often very much dearer, when it arrives at the feeding point, than it might otherwise be, solely on account of the high cost of the labour in handling it. Only too frequently hay is carried on the shoulders of a man from the rick-yard to the byre. With a grain crop, for instance, there is the pitching of the sheaves on to the thresher and afterwards the hauling away and distribution of the grain, straw and chaff respectively. To a large measure all work of this nature can be performed efficiently and speedily by the aid of mechanical equipment, preferably electrically operated.

In the field, the hay crop is often windrowed and by means of a hay-loader (hauled after the waggon) is elevated on to the vehicle. The portable, folding hay elevator for stack building is well known. Only too often, however, it is worked by a horse, though the mechanical oil engine is gradually stepping in to replace the animal. Where electricity is available, the oil engine is being, in turn, put aside in favour of the electric motor.

The employment of such elevators implies the slow forking of the loads by man power from the waggon. An improvement is to handle the crop by means of automatic grab-forks (Fig. 78), suspended from an overhead run-way and operated by an electric winch. While these grab-forks are very useful for dealing with parts of large stocks of fodder, each grab-fork load is still on the small side, compared with the whole contents of the waggon. It is now becoming customary to unload the carts in one lift. Fig. 79 shows a widely adopted method for dealing with hay or straw crops. The waggon used for carrying the crop from the field has a special carrier placed on it, for lifting off the whole load in one operation. In its simplest

form, this carrier consists of a long pole placed at the bottom of the waggon, with two pairs of ropes attached by clips to it at about two or three feet from either end. When the vehicle is loaded the ends of the ropes are hooked on to another lighter pole which is thrust horizontally across the top of the load, then the whole load thus roughly encircled, can be hoisted in one lot from the waggon, by means of an overhead run-way, operated by an electric winch, straight into a loft (Fig. 80). A three to five horse-power motor is large enough to drive the winch. The general arrangement of the rope work is similar to that of a Temperley transporter.

As an alternative to the pole and clip rope arrangement, rope nets are sometimes placed in the waggons before commencing the loading. Another method is to equip the waggons

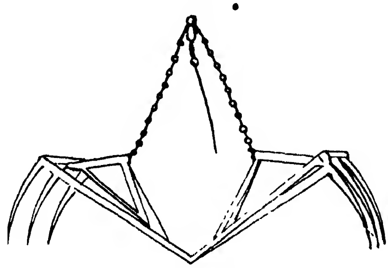

Fig. 78. Grab-forks for handling crops.

with removable wooden skeleton platforms. In this case the hoisting arrangement in the barn consists of a rectangular frame with ropes at each corner to clip on to the corners of the removable platform in the cart.

When the load reaches the required spot, the clips on the pole, underneath the load or at one side of a net, or at one side of a wooden platform, are tripped by means of a special tripping rope, thus allowing the load to fall at the required place. Given proper equipment, making the load drop in the right position is a matter of knack rather than skill.

In Sweden, some five thousand of these plants are to be seen on the farms; many thousands are also in use in Germany and other parts of Europe. Fabriken Odin, who manufacture many different types, have done a considerable amount of

work in educating farmers concerning the advantages of the mechanical handling of crops. Fig. 79 shows a load of hay being raised from the waggon. Any redistribution of the crop is usually made by the aid of grab-forks, which feed chain conveyors, which deliver to the final points of consumption. In the case of grain crops, fed to a threshing machine, an automatic device

Fig. 79.—Electric elevator unloading hay cart in one lift.

cuts the bands and a special feeder spreads out each sheaf after its band is cut and delivers it on to the threshing drum. Nowadays, it is becoming the practice for the threshing machines to be permanently mounted upon foundations at about four feet above the floor level. As the straw leaves the machine it is either baled or passes into a sheaf binder, or is blown to the straw-yard or barn through a tube, or else falls off to an inclined

elevator. Except where the pneumatic tube method is employed, the straw, whether baled, sheaved or loose, passes on to a horizontal conveyer. At convenient intervals, trap doors are placed in the run-way of the conveyor, which permit of the delivery of the straw at the desired spots. If required this first conveyer can be arranged to deliver on to another conveyer, placed

Fig. 80.—Load of hay passing down the barn.

just underneath and at any angle thereto. In this way the straw can be conveyed say across a roadway into a barn at right angles to the first. The various grades of grain are elevated by either Jacob's ladders (buckets mounted on endless belts), or spiral conveyers, which deliver on to horizontal belt type conveyers direct into the granary. Alternatively the grain is

handled pneumatically. The chaff is nearly always handled pneumatically, since the usual process of separation is by the aid of fans, so it is already floating in an air stream.

Most of the conveyers described above are of extremely simple construction, generally consisting of parts put together by the farmer with the aid of the local carpenter. Hence the capital cost is not great. The portable motors employed are usually only placed in position for the season—except, of course,

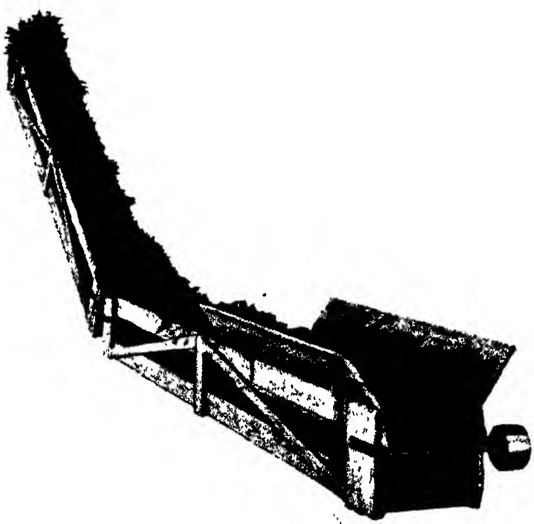

Fig. 81.—Crop Conveyor.

for conveyors that are used for re-distribution for stock feeding. To gain the utmost advantage of such mechanical means of transport, it is often advantageous to slightly re-arrange the barns and stackyards.

In Fifeshire, one of the first uses the farms connected to the electric distribution lines have made of electricity, is in the handling of the output of their threshing machines. The objection that it is not easy to erect elevators, etc., unless the buildings are built for the purpose does not hold good here, for the

Scottish barns, etc., are nearly all low-roofed, and apparently quite unsuitable, yet by many an ingenious little contrivance, it has been possible to install elevators and conveyers. Of course, if it is possible to build with a view to such installation, undoubtedly the best plan is to have a hay loft with an electric conveyer erected immediately over the stables and cow byres, as this affords additional facilities for feeding the horses and cattle.

There are a number of these elevators and conveyers to be found on the Continent to-day. Figs. 81 and 82 show the sheaves passing along the conveyer on to the platform of the threshing machine. The conveyer can be raised or lowered in accordance with the height of the stack. Many of these conveyers, which are driven by one horse power portable motors,

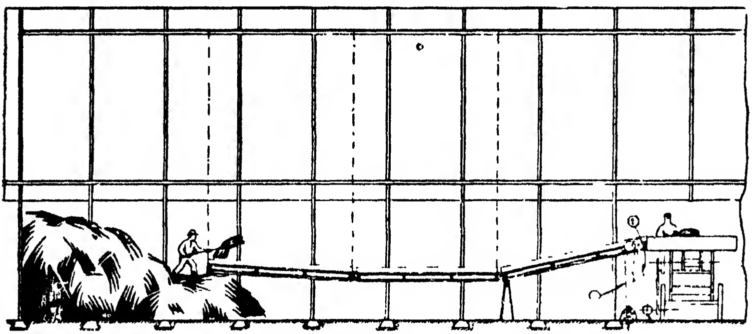

Fig. 82.—Sheaves passing from stack to feeding board of threshing machine

are so designed that they can be folded and carried from place to place on a farm waggon. The average machine deals with thirty sheaves per minute. With this apparatus, only one man and a boy are necessary on the stack, and one man on the thresher to cut the binder string and feed the machine. A grab fork is sometimes used for moving the sheaves to the thresher. (as shown in Fig. 83).

The length of the pneumatic delivery tubes are sometimes as much as two hundred yards. Five horse power motor driven fans will carry either grain or straw a distance of fifty yards, whereas an eight horse power motor will double the distance and a ten horse power motor will carry two hundred yards. Even smaller motors can be employed if fans of efficient design are util-

ised and also attention be paid to the form of the ejecting device.

With hay crops, Doctor A. Ekström, of Sweden, has estimated that in his own country a wagon load can be put into a loft at a cost of one shilling by means of an electrically operated elevator, whereas without it the cost works out at just under 1/4d. per load.

Cart Loaders.

Endless belts of about twelve inches or so in width, mounted on a suitable frame and electrically driven, are very useful

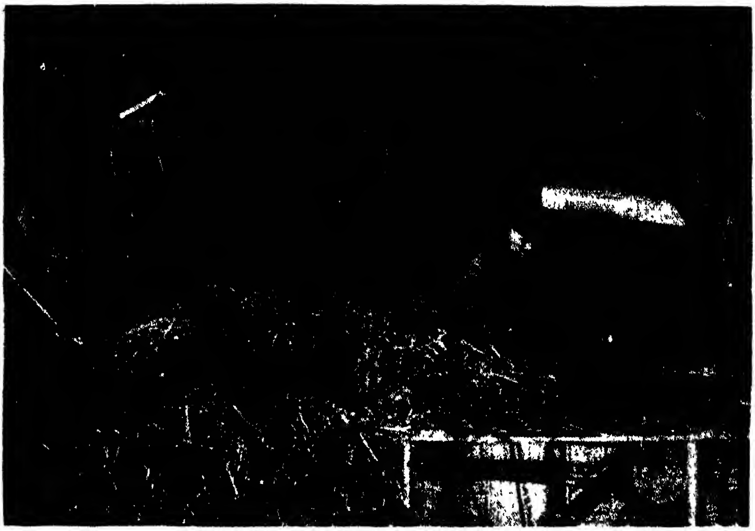

Fig. 83.—A Grab-fork used for carrying grain to the feeding board of the thresher.

for loading waggons with roots, stones and other materials. The framing carrying the belting is usually inclined at such an angle that grips or buckets are not needed on the surface of the belt. The whole arrangement is generally mounted on wheels of large diameter to facilitate moving it about.

Overhead Runways for cattle feed and manure carriers are often employed in cow-byres. However, the loads are light and the capital cost of a motor drive is too high to be worth while equipping these devices electrically.

CHAPTER XII.

THRESHING.

Decimal Class. 631.561.2E

Threshing is one of the important agricultural operations which can best be performed by electricity. The steady speed at which the electric motor runs, makes it possible to obtain a very uniform sample of corn; further, less grain is broken, so that the output of the electric thresher is five per cent. more than that of an ordinary thresher. This may not seem much, but as corn is a valuable article, it is well worth taking advantage of this extra gain. The electric motor with its smaller weight, its portability and the absence of any attendance during the work and its readiness to work at all times, is far more satisfactory than any other form of power.

Threshing equipment can be obtained with either motors fixed on to the machine (Fig. 84), or capable of being driven by portable motors. The former is the more satisfactory method, though a considerable number of the latter are to be seen on the Continent. Their popularity is no doubt due to the fact that, as the electric motor only consumes the amount of power required to do the particular work, it can be used for many other different kinds of agricultural work, such as for driving other barn machinery, circular saws and stone crushers, when the threshing machine is not required. The larger of the portable motors employed are usually mounted on four-wheel trucks, thus enabling them to be easily transferred from place to place. These motors are totally enclosed, so there is no danger when operating them in the barn, amidst the inflammable dust caused by threshing.

The threshing machines or mills may be of the portable or permanently fixed type. Fig. 85 shows a permanently fixed type of thresher. The latter are to be preferred as then it is

easier to arrange for the installation of elevators, mechanical or pneumatic conveyers, etc., to handle the various sorts of grains, chaff, straw, etc. Such fixed machines when properly installed, only require one hand to feed, one machine tender, and one man to control the supplies of sheaves to the feeder. This compares favourably with the dozen men required for threshing in the time honoured fashion.

The large types of portable threshing machines are only suitable for contractors, or very large farms, but the smaller machines are a great boon on the average sized farm, as they

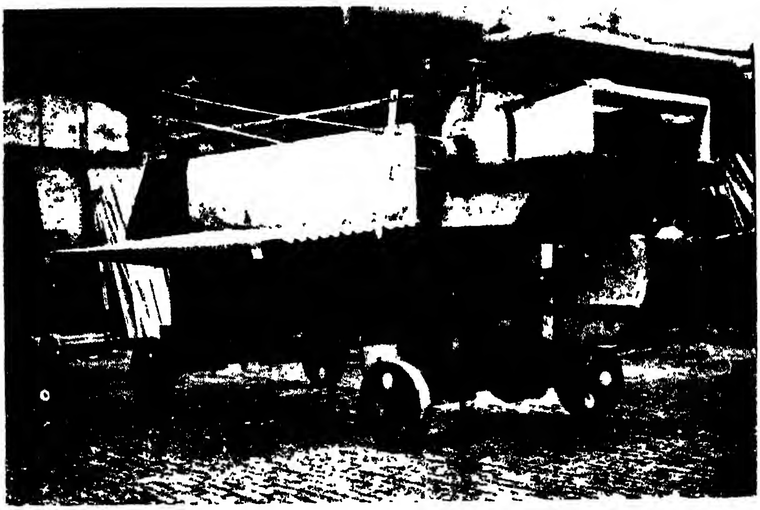

Fig. 84. Threshing machine driven by electric motor fixed on to the machine.

enable the farmer to thresh whenever it suits him, instead of having to await the convenience of a contractor. Some of these smaller machines are being made with a single cleaner and with a barley and oat awner, as they are primarily intended for the use of small farmers who use their own corn in preference to selling.

In order to reduce the maximum power required and also the number of hands employed, it is sometimes found advantageous to carry out the work in two stages. In the first machine the corn is threshed and cleaned sufficiently for the farmer's

Fig. 85. -Electric motor driving a permanently fixed threshing machine.

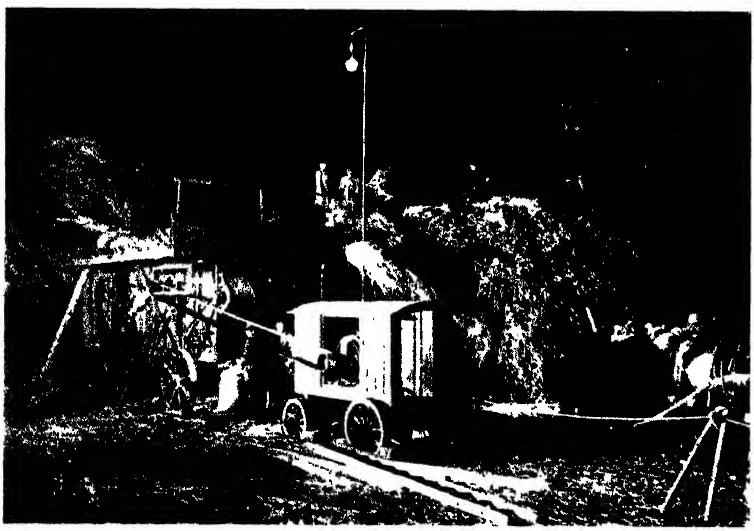

Fig 86.—Operating Thresher at night with portable motor outfit.

own needs. In the second stage, only that portion of the corn (from the thresher) that is intended for market is dressed, cleaned and graded. Either of these machines can be driven by a 5 horse power electric motor. Naturally, the whole process is spread over more days, but this is usually an advantage, as it obviates the necessity of employing temporary labour or neglecting other work. Further, it is often found convenient to do

Fig. 87.—Electrically operated thresher at Greater Felcourt.

the threshing in the late winter afternoons or early mornings, when it is too dark for the men to do other work. Fig. 86 shows a threshing machine operating at night. Electric lighting of course makes this feasible.

On his own farm the author has a six-foot drum ball-bearing threshing machine, which is operated by a five horse power

motor. (Fig. 87). It will thresh, clean and grade forty-five bushels of oats per hour and also drive a straw trusser. This particular machine, however, does not work so well with crops that contain a lot of weeds. For convenience, this thresher is mounted on a petrol-electric lorry chassis. When within reach of electric power mains, the motor is operated by them. When away from such a source of supply, current is obtained from the petrol electric generator, that provides the current to drive the lorry when in transit. The electric motor is direct connected to the threshing drum through a flexible coupling, the leather driving strap of which is designed to break if any foreign body should get caught in the threshing drum.

In the following table particulars are given of several tests carried out on Dutch farms with threshing machinery.

TABLE XVII.

COST OF POWER FOR ELECTRIC THRESHING.

(COMMERCIAL TESTS WITH ELECTRICALLY EQUIPPED MACHINERY).

Crop	Bushels	Time Minutes	Units consumed	Cost of power at 4d. per unit		Remarks
				s.	d.	
Barley*	50	60	5.98	2	0	Thresher equipped with treble cleaning apparatus.
Oats	50	60	5.24	1	9	--
Rye	52	150	12.3	4	1	6,300 lbs. of straw.
Wheat	98	140	11.0	3	8	—
Stacking straw	lbs. 1,100	113	0.72		3	The straw was unloaded from cart and blown on to top of stack, 33 ft. high.

*In this case the power consumption was checked by the Friesland Provincial Electricity Supply Co., and the grain weights by the local Agricultural Board, who certified the grain as "excellently market cleaned."

The daily winter load in the small province of Friesland, due to threshing, is 500 kW—which is well worth having.

When a trusser is used for baling the straw, the power consumption is increased by 1.8 units per hour, but three or four workers can be dispensed with. The cost of running the trusser is only 7d. per hour with current at 4d. per unit (kWh). In contrast with the above power cost of less than 4d. per quarter, a prolonged test on an oil tractor-driven thresher at a farm in Kent recently gave a power cost (inclusive of interest and depreciation, but not including tractor driver's wages or management expenses) of 2s. 4d. per quarter on 850 quarters (as audited by an expert accountant).

Interesting tests were conducted at Bloomington, Illinois, to determine whether electricity was the cheapest form of power for threshing grain. The cost of the steam threshing set was £954 and the operating costs were £315. One electric motor driven threshing set capable of performing the same amount of work cost £452 and the operating costs were only £133.

Particulars concerning elevators, conveyers, etc., for dealing mechanically with the products of the threshing machine will be found under the heading "Handling Crops" (p. 209).

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CHAPTER XIII.

ELECTRO-SILAGE.

Decimal Class. 631.563E

Silage is a heavy, damp, dark, strong smelling mixture, which can be obtained from grass which is usually turned into hay, though it is preferable to employ richer and more succulent substances, such as tares or other leguminous plants, as they can be most advantageously conserved for winter use in this way and the farmer is provided with a more nutritive food than hay, and one which can, to a large extent, serve as a substitute for roots. By the employment of silage, the acreage required per head of cattle can be considerably reduced, in fact, on some Continental farms it is as low as three-quarters of an acre per cow.

This method of conserving green fodder for the winter, has lately come into extended use. In America, the silo is part and parcel of every dairy farm. In East Anglia, there are now over four hundred of the modern type of vertical silos. This is largely owing to the adoption of vertical towers as silos, for when previously in vogue in England, some forty years ago, pits were utilised, which only too often produced sour silage, resulting in the abandonment of the practice for a time. Even with the tower silo, all is not satisfactory, for owing to the presence of certain bacteria, e.g., butyric acid, the milk from cows fed on it, cannot be successfully used for the making of butter or cheese. To overcome this and at the same time obtain a greener and more nutritious silage, the electric silo has been developed. While the only electrical method of making silage in this country exists on the farm of the author, the process has made great strides on the Continent, where many hundreds of such silos are in existence. It is known that the vegetable cell of plants is destroyed when heated up to 120 deg.

Fahr. (50 deg. Cent.) and at this temperature the growth of the various kinds of bacteria essential for good preservation is increased. This rise in temperature in the electric silo is produced by passing an electric current through the fodder which latter acts as a resistance. As it is a heating process, both alternating and direct current can be used. Where three-phase current is available, it is customary to construct three silos side by side and then the phases are approximately balanced. About six feet of fresh material, chopped small to exclude air pockets, is treated at a time. The current starts at half an ampere and at the end of twenty-four hours has increased to thirty amperes, when the process is complete.

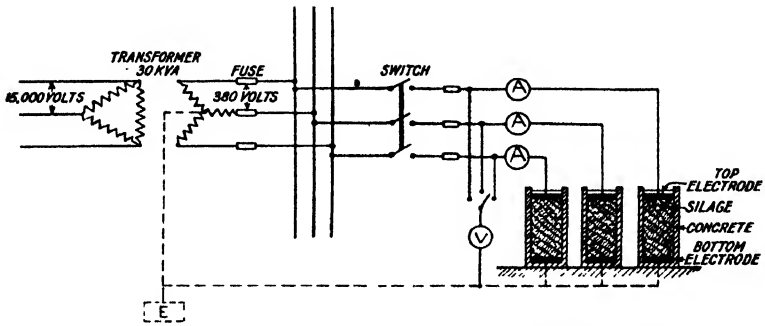

Fig. 88.—Electrical preparation of silage.

The accompanying diagram (Fig. 88) illustrates the general arrangement. Each silo has an earthed electrode fixed at the bottom, and a live electrode is placed on top of the freshly-cut chopped green-stuff. Up to 10 kVA is required for a silo of about 20 ft. (6 m.) in height and 14 ft. (4.25 m.) in diameter, and the time required is twenty-four to forty-eight hours.

Good preservation depends upon a rapid development of the lactic acid bacteria, which is produced by a quick and even temperature rise. When these bacteria multiply rapidly, they tend to stop the growth of the butyric and acetic acid bacteria which impede the process of preservation. In this way, the electric current by evenly and quickly increasing the temperature of the fodder to about 120 deg. Fahr. (50 deg. Cent.), brings about the desired result. After the heating process has been

carried out, the temperature of the fodder is allowed to fall to that of the surrounding air, and the detrimental after-fermentation is avoided. The latest development in electric silos is a modified and modernised pit. With this method, the fodder is placed in position, in sections, being held in place by removable barriers. Electric tubular heaters are plunged into the material through apertures in the barriers. This process takes a comparatively short time and the load is kept constant, during the whole time that the silage is under treatment. The pits are brick or concrete lined and measure about 6 ft. (2 m.) high by

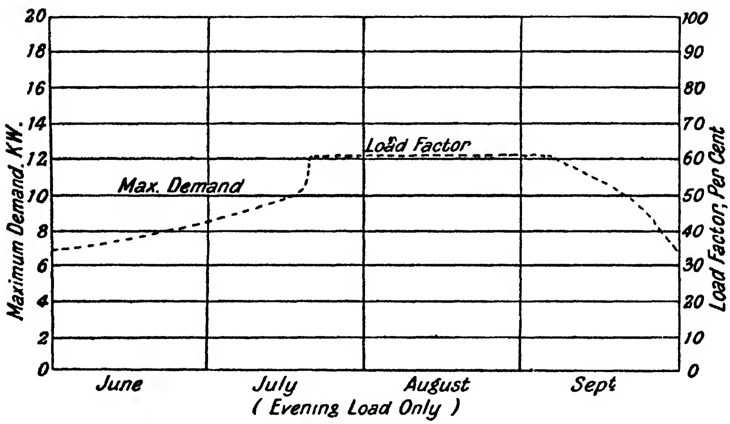

Fig. 89.—Load factor and maximum demand of an electric silo dealing with 100 tons of silage.

6 ft. (2 m.) wide and about 40 ft. (13 m.) long and are arranged for the reception of temporary barriers every 6 ft. (2 m.).

A cow consumes from 20 to 30 lbs. (10-15 kg.) of silage per day. This means a consumption of about two tons per head for the winter months. Normally 100 tons of silage is provided for fifty head of cattle. The current consumption for preparing one cwt. (65 kg.) of green stuff is one to one and a half units (kWh), say, 1.25 units (kWh) or 25 units (kWh) per ton. Taking 30 units (kWh) per ton of cured silage this means about 60 units (kWh) per cow per annum. The accompanying diagram (Fig. 89) shows how the maximum demand and the load factors work out, on an electric silo dealing with 100 tons of silage.

Incidentally, crops can be gathered and ensiled over a longer portion of the season, if the variety of seed and time of sowing are properly arranged. Thus the work can be more evenly distributed over the season than is the case with hay.

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CHAPTER XIV.

ELECTRO-CULTURE AND LIGHT TREATMENT.

Decimal Class. 631.588.1

TABLE XVIII.

USES OF ELECTRICITY IN ELECTRO-CULTURE AND LIGHT TREATMENT.

Discharge over crops through earth currents.
Treatment of Seeds.
Treatment of Plants by intensive illumination.
Pollination.
Heating of Greenhouses.
Destruction of Pests.

History of Electro-Culture.

Experiments for the electrical stimulation of plant growth have been carried on for about one hundred and fifty years. At first, atmospheric electricity was used, and one of the first experimenters to announce the success of his methods was Abbe Bertholon in France. He found that by conveying atmospheric electricity to growing plants their fertility was increased and their appearance improved. Many other similar experiments were carried on at this time and the general result showed that the possibilities from this source were very promising. Work on these lines is still being carried on by a number of experimenters.

As far back as 1746 an account was published of an Edinburgh physician who electrified two myrtle trees and surprised his neighbours by making them shoot their branches and blossom earlier than any in the neighbourhood. Similar experiments were carried on for a number of years, but it was not until about 40 years ago that it was actually proved beyond doubt that the growth of plants was actually stimulated by electricity. This was due to Professor Lemstroem, of Helsingfors University,

who, while visiting Polar regions, was struck by the rapidity with which plants grew in the short Arctic summer, where both the heating and illumination effect of the sun were very low.

Professor Lemstroem realised that it was necessary to look for some unrecognised cause for the remarkable development in the vegetation of these regions. He eventually discovered that this was caused by electrical currents which occur in the Polar light and which travel from the atmosphere to the earth and vice versa. In his book dealing with this subject he says: "An electrical current is going on through the needle formed leaves of the pine and the beard on the ears of the cereals, not to particularise on other plants." To prove this he arranged fine metal points around the plants and succeeded in registering the current flowing.

Immediately on his return to Finland he set on foot experiments which proved that an electrified crop would produce a far larger yield than an untreated one. He subsequently continued his work in England.

In this country, Sir Oliver Lodge and other experimenters conducted electro-culture experiments by means of a high tension electrical charge on an overhead network. (Fig. 90). In 1904 experiments were conducted by Mr. J. E. Newman on the farm of Salford Priors, near Evesham (Figs. 91 and 92), with apparatus designed by Sir Oliver Lodge.

The history of electro-culture is crowded with the names of illustrious students. Gardini (Turin), Ingenhousz (Vienna), Landriani (Madrid), Carmoy, Rouland, de Rozieres, Nollet, Jallabert, Du Petit Thourars, Gasc Becquerel, in America, Pine, Weekes, Foster, Ross, and in Great Britain, Lemstroem, Blackman and Miss Dudgeon have all added their quota to knowledge of this subject. In our own country the Electro-Culture Committee appointed in 1918 by the Ministry of Agriculture and Fisheries has covered a wide field of research, and in America a somewhat similar Committee has been at work.

Electrical Treatment of Crops.

Among the very great difficulties associated with the treatment of crops electrically (otherwise than by electro-mechanical processes) is the lack of definite information concerning soils, coupled with an absence of exact knowledge of the actual effects

to be obtained from electrical treatment, and the form of current that is most suitable. Farming is a commercial proposition and hence it is impracticable to modify the fields so that they may become perfect bacteriological and chemical beds for the proposed crops, even if it were known how to attain this end. As things are at present, every field, and further, every part of that field, has its own peculiar characteristics. At present

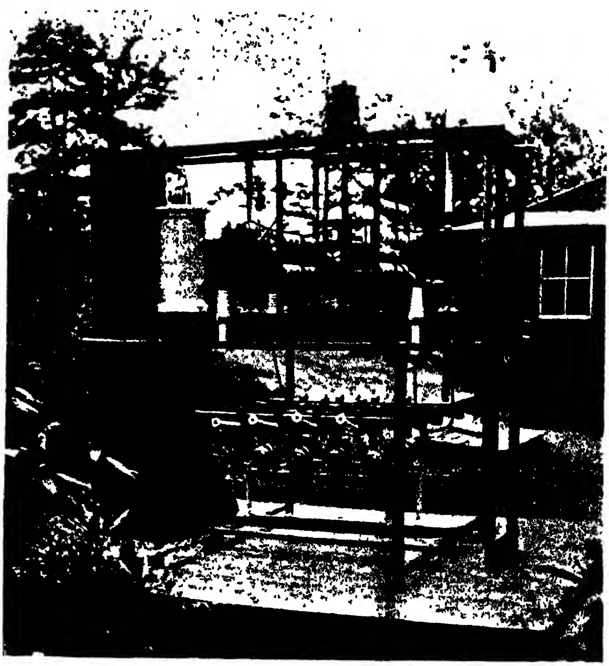

Fig. 90.—An Electro-Culture High Tension Discharge Apparatus installed at Greater Felcourt, East Grinstead.

there are no practical means of discovering these characteristics in advance, so altogether it is very difficult to ascertain what results are obtainable, that can be directly ascribed either to electrical treatment, the properties of the ground, or the effects of weather. On the whole, a careful comparison of a great many experiments on large scale conditions show that there is undoubtedly a considerable improvement in those crops which are electrically treated.

Fig. 91. -Unelectrified wheat at Evesham.

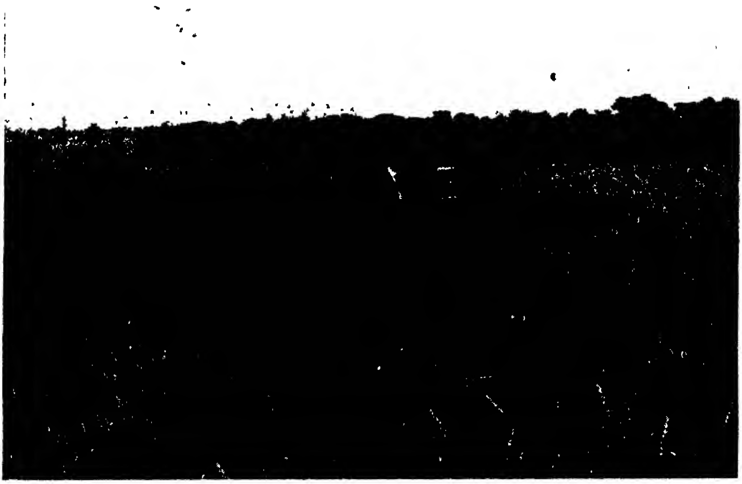

Fig. 92.—Electrified wheat at Evesham.

The cost for current is negligible—in fact, so much so that the problem has little interest for the electricity supply undertaking, which only desires to increase its immediate sales of current. The chief question, therefore, that really has to be considered is the commercial one as to what amount of capital is necessary to attain this increase in the crops. The cost of stringing the wires is not at all an important matter, for 4 or 5 lbs. of fine wire (29 gauge) is all that is required per acre, plus the heavier insulator borne cable supports around the field.

The Lodge apparatus, by means of which the 1904 experiments conducted by Mr. J. E. Newman were made, consists of a large induction coil with spark gaps and motor driven contact breaker in conjunction with two-plate Lodge valves through which only positive current can pass, as uni-directional current is required, the charge on the wires being positive. The current was transmitted by over-head wires to the fields, and conducted around the field by means of a substantial wire, which was attached to large insulators mounted on poles. From this wire, very fine wires, spaced from 10 to 30 feet apart, were run across the field. The wires were placed from 12 to 15 feet from the ground, so as to allow carting and other farm operations to be carried on without interference.

The serious factor is the cost of the transforming and rectifying apparatus. At Harper-Adams' College, for instance, the cost of the equipment for an area of just over 2 acres, was as follows:—

	£	s.	d.
Aerials	5	0	0
Insulators	11	15	0
Motor Generator	125	0	0
Transformer	200	0	0
Instruments	25	0	0
Erection, carriage, etc.	33	5	0
Total ..	£400	0	0

The plant was considerably underloaded and so could have dealt with a much larger area, with a small additional cost for aerials, insulators and their erection. The consumption was at

about the rate of $1\frac{1}{2}$ units per acre, and electrification was carried out for 8 hours daily (7—11 a.m. and 3—7 p.m.) weather conditions permitting. The average height of the wires above the ground was 6 ft. 0 in. and they were placed about 5 ft. 6 ins. apart. Approximately 4 lbs. of wire was required per acre. A 1 kVA oil-cooled, 25 cycle, single-phase Ferranti transformer was in use, as at Rothamsted. It was provided with tappings for 15,000, 30,000, 45,000 and 60,000 volts. The secondary current was from 0.066 to 0.01666 amperes. The normal voltage employed was 45,000 volts and the current supplied to $2\frac{1}{6}$ acres was approximately 1.7 milliamperes. The high tension current is made unidirectional by means of a rotating Newton and Wright disc rectifier mounted on the motor generator shaft. It is estimated that the capital cost of a hundred acre equipment would be about £4 per acre.

By deduction from the experiments which have so far been carried out, the most suitable arrangement for a commercial farm is to provide an alternating-current supply ; a 100,000-volt high-tension, oil-cooled transformer ; and a mechanical rectifier driven by a small synchronous motor. The overhead network should be placed 15 ft. above the ground. It would probably be necessary to operate such a plant only for about an hour in the morning and again in the evening, during the spring and early summer months. The transformer would be preferably switched on and off by a time-switch. A Lodge or similar valve would probably give a more efficient discharge than a mechanical rectifier, but on large-scale work these valves do not appear to be so practicable. In the course of time it seems quite likely that the transformer may be superseded by a motor-driven influence machine. Owing to the low power factor of these installations it is necessary before accepting the readings of any instruments, to see that due corrections have been made.

The Tesla transformer (employed at Lucerne) on small scale, but successful experiments, was very attractive from the point of view of absence of danger of accidental shock to farm labourers or animals. However, the principle involved of the utilisation of very high frequency currents is opposed to British practice of low frequency, uni-directional currents, and therefore would seem to require further investigation, as so much

more work has been done along these lines in Great Britain. Alternative methods of producing a high tension current for electro-culture purposes are by means of a large number of dry cells in series (a very simple method), also by means of an apparatus similar in design to the Dallon cable testing machine. (This device can be constructed for about fifteen pounds).

Various theories have been put forward as to the reason for the effects produced, e.g., that the discharge forms nitrogen compounds, ozone, etc., producing manurial or plant-feeding effects. However, the quantity of electricity used is so small that only an infinitesimal amount of manure or its equivalent could possibly be produced, even under the most favourable conditions. Hence, the author's deduction is that it is entirely a physical, stimulative effect, which is practically the opinion of Professor V. H. Blackman, who has carried out a great deal of experimental work on this subject, both in the laboratory and on the field, on behalf of the Electro-culture Committee of the Ministry of Agriculture. While it would be very interesting to arrive at a definite conclusion as to the theoretical basis for the improvement attained in the growing of crops that are electrically treated, the fact remains, that better results *are* obtained, and also the cost of carrying out the electrical treatment (apart from considerations of the capital required for the installation) is nominal.

The employment of short heat waves, from luminous electric heater lamps, has been suggested and experimented upon. However, the experimental scale has been a small one, and it would seem that the power consumption necessary is likelyto be very great.

United States Experiments.

In the United States experimental work on electro-culture has been carried out for over 70 years, and whilst indications of increase in crop yield have been observed, this has not been the universal result. In fact, in the case of the experiments conducted under the Office of Biophysical Investigations of the Bureau of Plant Industry it is stated that no marked response to the treatment was shown. Nevertheless, the work done on the Arlington Experimental Farm is an interesting record of painstaking observation. During the period of 1912 to 1915 the Lodge apparatus was used. This consists of 110 volt induction

coil, with a motor driven mercury interrupter. Five Lodge valves designed to rectify the high-tension alternating current were placed in series with the network, thus allowing only the

Table XIX.

SUMMARY OF THE RESULTS OF THE ELECTROCULTURAL EXPERIMENTS IN SECTIONS A, B, AND E, ARLINGTON EXPERIMENT FARM, IN STATED YEARS.

(The treated and control plots in sections A and B were each three-fourths of an acre in area; those in section E half an acre each, separated by an interval of 350 feet. *Abbreviations and symbols.*—Column 2: C = Cow-peas (crop cut for hay); R = Winter rye; S = Soyabeans; W = Winter wheat. Column 3: A = 25-cycle alternating current; N = No treatment; — = Negative direct current; + = Positive direct current. Column 11: * = Yield of plots treated in previous years).

Section and date	Crop	Network treatment: Character of current: Charge	Network treatment: Character of current: Voltage	Network treatment: Description of Network: Height (feet)	Network treatment: Description of Network: Spacing (yds.)	Network treatment: Time of treatm'nt (hours): Per diem	Network treatment: Time of treatm'nt (hours): Total duration	Yield (pounds): Straw: Treated	Yield (pounds): Straw: Control	Yield (pounds): Grain: Treated	Yield (pounds): Grain: Control	Ratio of treated to control: Straw	Ratio of treated to control: Grain
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Section A													
1914	S	A	6,600	16	5	-	—	2,776	2,446	811 3	782.5	1.13	1.04
1915	R	A	6,600	16	5	—	—	2,662	1,758	981	700	1.51	1.40
1916	R	N	—	16	5	—	—	2,700	2,558	*1,147.5	803	1.44	1.43
Section B:													
1912	W	+	45,000	7	1	*a*16	—	3,465	3,300	1,154	1,114	1.05	1.04
1913	W	+	40,000 to 50,000	16	10	*b*16	—	3,254	3,139	808	782	1.04	1.03
1913	C	+	45,000	16	10	*b*4	128	1,807	1,847	—	—	.98	—
1914	Corn	A	—	16	10		—	6,952	6,212	2,892	2,260	1.12	1.28
1915	R	A	—	16	10	—	—	2,836	2,758	1,046	1,040	1.03	1.01
1916	W	N	—	-	—	—	—	3,016	3,412	*861	1,009	.88	.85
Section E													
1913	R	N	—	—	—	—	—	2,438	2,499	—	—	.98	—
1914	W	+	30,000 to 60,000	16	5	*b*4	336	2,332	2,281	644.8	656.5	1.02	.97
1915	W	+	30,000 to 60,000	16	2	*c*6½	345	1,548	1,362	624.5	604.5	1.14	1.03
1916	W	—	45,000	16	2	*a*16	800	2,528	2,444	672	754	1.03	.89
1917	W	N	—	—	—	—	—	3,190.5	3,064.5	1,137.5	1,198.5	1.04	.95
1918	W*d*	+	30,000	16	1	*a*16	736	2,820	2,639	*1,050	1,025	1.07	1.02

a From 4 p.m. to 8 a.m.
b From 3 to 7 p.m.
c From 4 to 7 a.m. and from 5 to 8.30 p.m.
d Plots separated by grounded wire screen.

positive impulses from the secondary of the coil to reach the network. The negative pole was grounded. Two balls 25 millimeters in diameter, one of which was grounded and the other

connected to the network, were used to determine the potential, assuming a breakdown gradient of 3,000 volts per millimeter.

The treatment was usually given during the early morning and late afternoon, and although there was a slight increase in the yield of wheat, the official report points out that this might well be within the experimental error of field trials. Table XIX. is taken from the above-mentioned official report, as it summarises investigations over a period of five years.

In this country electro-culture experiments have been carried on at Rothamsted, Durham College, at Lincluden (Miss E. C. Dudgeon) Gerrard's Cross, the Royal Horticultural Society Experimental Garden at Wisley, at Evesham and at East Grinstead. The table herewith summarises the results of the experimental work above mentioned.

Table XX.

TABLE OF REPRESENTATIVE RESULTS OBTAINED WITH ELECTRO-CULTURE IN THIS COUNTRY.

Crop.	Normal, un-electrified crop per acre.	Increased crop per acre when electrified.	Authority.	Increased value of electrified crop per acre (on pre-war average prices).
		Per cent.		£ s. d.
Wheat	35 bushels	39	Newman	3 0 0
		29	Newman	2 4 0
		38 (straw 41)	Rothamsted	2 18 0
		49 (straw 88)	Blackham	3 15 0
Oats ..	40 bushels	30	Dudgeon	2 2 0
		49	Dudgeon	3 9 0
		50	Dudgeon	3 10 0
		57	Dudgeon	4 0 0
Barley ..	40 bushels	35	Rothamsted	1 15 0
		19	Rothamsted	0 19 0
Peas ..	27 bushels	20	Lemström	2 16 0
		28	Lemström	3 18 0
Potatoes ..	6 tons	37	Dudgeon	11 0 0
		15	Dudgeon	4 10 0
		50	Newman	15 0 0
Carrots ..	10 tons	50	Newman	15 0 0
Mangolds ..	20 tons	25	Newman	4 0 0

Ministry of Agriculture Investigations.

In 1918 the Ministry of Agriculture and Fisheries set up an Electro-culture Sub-committee and between then and 1925, this Committee has investigated and experimented with crop treatment. During the first four years the work done was chiefly directed towards ascertaining the type of electrical apparatus most suitable for the production of high tension discharge, the current which should be used and the effect of the same upon spring cereals. It was found that if the distance apart of the overhead wires was not greater than their height from the ground, then half the current supplied to the wires may be expected to reach the crop and also the electrical influence of the apparatus would be felt in a greater or lesser degree well beyond the wires. As far as spring-sown cereals are concerned, an average increase of 20 per cent. was experienced. From 1922 onwards, pot and field experiments were extensively carried on, in fact, in view of the striking results obtained in 1922 from pot culture experiments, field work was temporarily discontinued and all energies were concentrated upon pot culture and laboratory work. The result of this was, that by the end of 1923 it had been established that one month's electrification in the case of spring-sown cereals was more effective than electrification for the full three months. General experience inclines the author to imagine that the first month is always the most important and therefore the one during which treatment is most beneficial. Results of experiments of this nature must be looked into carefully before their full meaning becomes apparent, for instance, that a relative decrease in the total yield of a crop may still mean an increase in grain yield has been found to be the case at Lincluden, where the total decrease in yield was 7.2 per cent., but where at the same time the increase in grain yield over the corresponding control plants was 33.2 per cent.

Experiments were conducted at Rothamsted Experimental Station, Harpenden, Hertfordshire, while small plot experiments with oats were likewise conducted at Lincluden, Dumfries. The laboratory work was carried out at the Imperial College of Science and Technology, South Kensington.

Earth Currents.

More than one hundred and fifty years ago, experiments were being carried on in the utilisation of earth currents, and now the accumulated experience of this experimental work has been taken advantage of, more particularly in France, Switzerland, and Germany. In Basty's method, lightning conductors

Fig. 93.—A Christofleau apparatus installed near a row of kidney beans.

are erected in the middle of the growing crops, the earth ends of which are buried in the ground, and carried under the roots of the plants to be treated.

In the Journals, "Science et Commerce Industrie Mutualite" and "Le Progres Agricole," Basty, describing the results of some of his recent experiments, states that potatoes grown

on an experimental plot were ready for lifting a week earlier than those on the control plot and there was an increase in the yield of 68 per cent., while an experimental plot of hemp showed an increase of 252 per cent. on the control plot. There were other methods for stimulating the growth of plants in days gone by. Christofleau has recently put upon the market a piece of apparatus, similar in principle, but also incorporating a thermopile and a voltaic pile. The device consists of a number of points mounted in a casting and fixed at the top of a pole.

Fig. 94.—Interior of the high tension house showing the installation used in experimental work in Holland (Haarlemmermeer).

This fixture is connected to the ground by galvanised wire, which latter is run in a northward direction for some distance, just below the usual digging depth in the earth. (Fig. 93).

The posts upon which this piece of apparatus is placed must be at least 20 feet above the ground and should be buried at least 2 feet below the ground. The posts should be placed every 10 feet if it is desired to extend the sphere of the current for a complete field. A modern improvement is the addition to the apparatus of a thermopile, which is a tube of two different

metals, by means of which is set up a small electric current, due to the exposure of one joint to the heat of the sun. The treatment should be continued each year for six years and at the end of this time the maximum capacity of reproduction is reached and the crops from this land will thus remain at their highest stage of productivity. Further, it is claimed that there is no need to add fertilizers to the soil.

Earth current experiments are being successfully carried out by others in France, Switzerland, Germany (Klein-Glienicke),

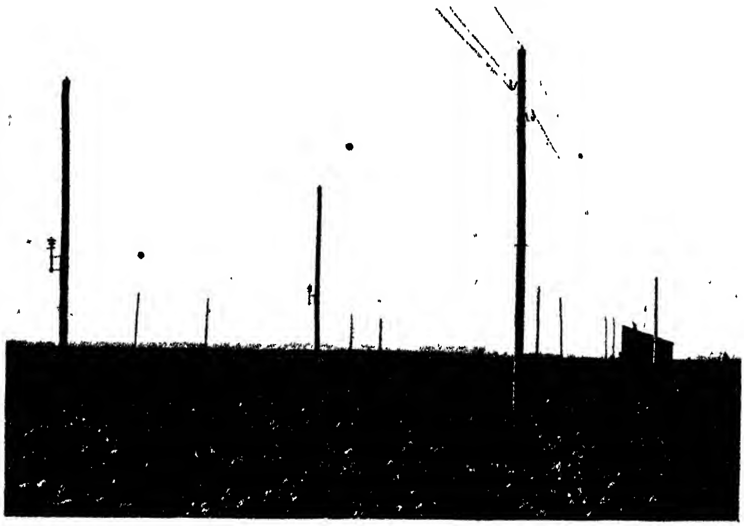

Fig. 95.—Aerial installation for electro-culture work at Haarlemmermeer.

Morocco, India, and the Argentine, in which latter place it is stated that a remarkable difference can be observed in the oats, rye, barley, wheat, corn, sugar beet, potatoes, cabbages and flax grown under the influence of this apparatus and the crops not touched by this influence. There is a Christofleau installation in the garden of the author, but it has not been installed for a sufficient length of time to justify conclusions. Still, plants within the sphere of its influence have been, this year, noticeably superior to non-treated plants on adjoining plots.

The illustration given in Fig. 94 shows the interior of a high tension house, used for experimental work on electro-culture in Holland (Haarlemmermeer). On the right can be seen the 100,000 volt transformer. On the lower left hand side, another transformer will be found for heating the filaments of the rectifying valves with spherical bulbs which can be observed on the table. The operation of the installation is controlled by automatic electric time switches mounted on the wall in the centre of the picture, above the meters. Fig. 95 shows an aerial installation for electro-culture work at the same place. As will be observed, the placing of the poles and the height of the wires are such that they do not interfere with field operations.

Electricity for Potatoes.

During 1925, the claim of Mr. R. A. Rushforth to increase the yield of his potato plants in weight by 51 per cent. by electrical treatment, aroused a good deal of attention. Besides the increase in weight, it is claimed that potatoes produced are free from attack by pests or blight and that the plants are healthier and stronger and have thicker stems than those which had not been subjected to the treatment. It is noteworthy that it is not claimed that the process of maturity was hastened by the treatment.

The illustration (Fig. 96) given herewith shows Mr. Rushforth's ingenious make and break apparatus. This consists of a small wooden balance about 6 in. or 7 in. long pivoted in the centre. On one end is fixed a small lead weight, which causes the balance to rest in a horizontal position on a supporting peg below. On the other end of the balance is fixed a tin lid, into which water drips from a pail above. The accumulated water is sufficient to overbalance the lead weight, and this, at its highest position, hits against a spring, thereby closing two contact points momentarily. The water empties from the tin lid after causing this electrical contact, and the balance returns to its original position. The rate of dripping water can be adjusted so as to cause contact to be made as required. Thus, at regular intervals, is discharged a momentary current through a small shock coil, the diameter of which is 2 inches and the

length 6 inches and from thence is borne through a long wire to two strips of sheet copper buried about 6 inches in the ground one along each of the two opposite sides of the plot set apart for experimental work.

Mr. Rushforth planted his potatoes, then daily applied shocks for one second at regular intervals of half a minute.

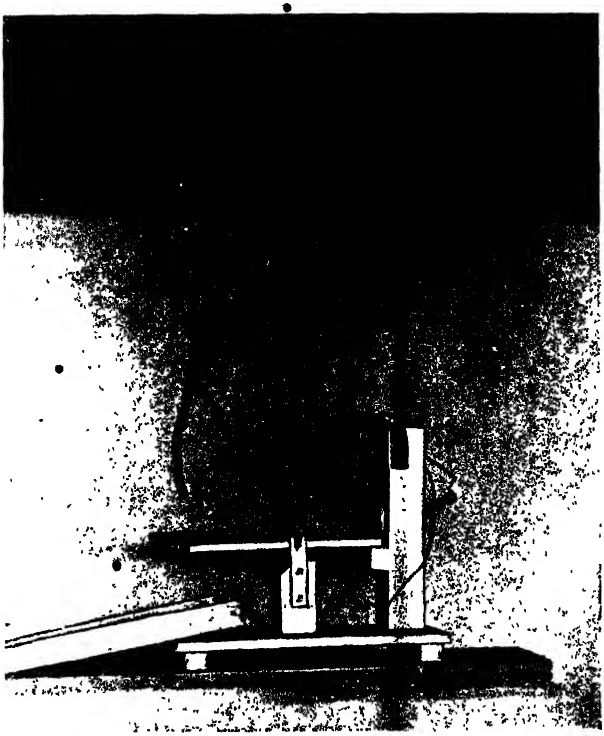

Fig. 96 —Mr. R. A. Rushforth's device for automatically switching on and off the current for potato growing.

The current for the whole season was supplied by three Leclanché cells, although the size of the plot was about an acre and these cells were charged once only (at the beginning of the season). It is noteworthy that wire worms, slugs, grubs, etc., kept away from the electrified potatoes. Further corroboration is required, as one season's experimental work in agriculture is of little avail.

A simple type of apparatus has been installed by Mr. A. R. Hill in the garden of a Walsall school. Experiments were made on three different plots, with potatoes, peas, beetroot, beans, lettuce, radish, tomatoes and nasturtiums, electrical current being applied by means of zinc and copper plates connected by an overhead wire. With potatoes it was interesting to observe that the greatest success was not obtained with the plants nearest to the electrode. Control plots on the other side of the garden made it possible to estimate the value of the electrical current. An increased crop of potatoes was obtained. In the case of beans there was a loss of produce, but what were grown were ready for market earlier and were thus of more value. Beetroots may be planted earlier than their usual time if electrical treatment is to be given.

Electrical treatment of seeds.

As has been seen in the historical survey of this section, the treatment of seeds is one of the oldest of the branches of electro-culture. Sceptics who are inclined to believe that electrical treatment can have no effect upon a seed should be convinced by the simple experiment made upon potatoes by Mr. A. E. Baines. Taking two potatoes, he boiled one for fifteen minutes and baked the other for the same length of time. It might reasonably be supposed that such treatment would render the potatoes incapable of sprouting, but after passing a current of electricity through them for twenty-four hours, vigorous sprouting was observed in both specimens.

A seed consists of an outer dry membrane (the seed-coat) and a fibroid or lipoid layer between it and the seed proper, which latter has yet another thin, protective membrane. A seed is electrically inert, and before growth can commence, the seed-coat must be rendered conductive. The electro-static capacity of the seed is therefore a matter of great importance. This depends on (1) the resistance of the seed-coat, (2) the specific inductive capacity of the fibroid or lipoid dielectric, and (3) the nature and quantity of the liquid content of the seed-substance. Experiments show that electric treatment of seeds effects the plumule, radicle and cotyledons, thus insuring early maturity.

The longest-known commercial process in this country, by means of which seeds have been electrically treated, is the Wolfryn Electro-Chemical Process of Seed Electrification, which is essentially simple and which could easily be carried out on a farm where a supply of power is available. All that has to be done is to place the seed to be treated in a bath containing a suitable metallic salt (4 ozs. to the gallon). Common salt will easily suffice, but it is found to be worth while to adopt the kind of salt best adapted to the nature of the soil in which the seeds are ultimately to be grown. Calcium and sodium chloride are salts often used, as both of these are plant foods. One bushel of grain should be soaked in five gallons of water (although oats will need five and a half gallons). The period required for soaking before the passing through of an electrical current should be two or three hours in the case of wheat and slightly less for barley and oats. After this soaking, electricity should be applied, the amount of current required being two amperes per sq. ft. of the active surface of one of the electrodes. Electrical treatment should last for from three and a half hours for wheat or rye, to seven hours for barley and maize; after which the seed should be left to soak for a further sixteen hours without electricity. Then the water should be run off and the seed allowed to drain for an hour. Excessive moisture can next be removed by spreading the grain on the floor and sprinkling it with slaked lime, and within twenty-four hours it will be ready for sowing. Although it can be safely kept for some time, it is better to sow promptly. This process, it is estimated, cannot cost a farmer more than a few pence per sack to execute.

Obviously a process is judged by its results, and the Technical Committee of the Food Production Department of the Board of Agriculture have investigated the Wolfryn process. The Board of Agriculture reported an average increased yield of 30 per cent. from seed treatment, following the lines of the process.

In Australia, Mr. A. Carr Bennett has done much pioneer work in the application of electricity to vegetable seeds, and his work was first instigated by his discovery of the effect of a thunder-storm upon growing plants. Mr. Bennett started by using a three-inch medical induction coil, together with (1)

contact breaker, (2) flexible insulated wires with terminals, (3) a metal foot-plate, (4) two electrodes, and (5) three plug sockets and a switch fixed on the wooden framework that carries the coil. A great deal of the success of this treatment depends upon soaking the seed for the correct length of time before treatment.

The results obtained are almost monotonous in the uniformity of their excellence. The advantages of the treatment may be summarised as follows:—(a) an increased number of seeds germinate, e.g., with Canadian Wonder Peas under test it has been found that 93 per cent. of the seeds planted germinated, (b) electrification helps in the struggle against weeds and pests, such as red ants, (c) increase in the quality and quantity of the yield.

One farmer in Queensland states that he has netted £300 from an acre of cucumbers from electro-cultured seeds (the usual return from this area—non-treated seed—never being in excess of £100). Another has taken three cases of tomatoes, over a pound weight each, from a single tomato vine grown from electrified seed. Again, another farmer tells of beet, four pounds in weight, and four times the usual size. At the trial grounds, lucerne has been made to grow in unsuitable land where the untreated seed absolutely refused to grow. Most beautiful blooms have been produced far in excess of size and brighter in colour than from untreated seed. Mr. Bennett emphasises the fact that the soil upon which some of his best results have been obtained is below rather than above the average in quality. The disadvantage of all electric methods of seed treatment seems to be that the germ is weakened in its ability to resist frosts. Hence an unexpected frost may destroy the greater part of a crop that had not fully established itself.

Treatment of Plant Life by Intensive Illumination.

Somewhere about 1686, an English botanist, John Ray, recorded what he had observed to be effected by the total absence of light on plant life. This appears to be the first indication that light was recognised to have an important influence on plant life, and it was nearly 100 years from that date before other botanists investigated the question of the influence on plants of total darkness. No sooner had it been discovered that light is one of the most important factors in plant growth, as it increased the

proportions of carbo-hydrates, than it was naturally concluded that artificial light would have a beneficial effect on plant growth.

It is noteworthy, that in this field of work there is a bigger record of experimental work than can be found in any other. This is largely because there is a double impetus to success in this direction. (1) Market gardeners and all agriculturists growing vegetables, flowers, etc., for profit, naturally have an interest in any process which might be expected to hasten maturity of growth, and this purely commercial reason also affects the question where orchids and other rare flowers are concerned. (2) It is of inestimable value to plant breeders to be able to test their hybrids in the shortest possible time. For instance, if new types of wheat, oats, etc., can, as has been done, be grown in four different crops in one year under the influence of artificial light, the seed breeder is saved exactly three years experimental work. Further, this hastening of maturity in plants is invaluable to the man who is investigating the diseases of plants. In the past cultures of parasites have been lost during the winter, owing to the impossibility of keeping them alive and well nourished. This difficulty can now be overcome.

The inconsistent results which so many experimenters have experienced, are probably due to insufficient allowance being made for factors other than light itself, which should enter into the calculations of the experimenter.

The chief factors to be considered are as follows :—

(1) Light. Intensity, Duration, Colour.
(2) Air. Quantity, amount of Carbon-Dioxide, Humidity.
(3) Soil. Moisture, Food value, composition. Bacteria and mould content.
(4) Temperature.
(5) Normal habits of the plant.

To find the effect of any one of these, all the others must be kept constant. Further, there is a certain value of each which will give the best results with each species. For instance, intensity of light must be within certain limits to produce normal developments. These limits vary very widely for different species of plants ; as a rule those plants having leaves very much divided up require the greatest intensity.

As regards reaching the flowering stage only, the intensity is not of such great importance, for it has been found possible, by regulating other influences, to make plants develop normally with much lower intensity than is needed in nature. There is, however, a certain figure below which no blooms are formed.

The following table, which is largely based on the work of Mr. Esten Hendricks and Dr. R. B. Harvey gives suitable intensities for various plants :—

TABLE XXI.

BEST INTENSITIES OF LIGHT FOR MAKING PLANTS BLOOM AND PRODUCE SEED.

Plant.	Temperature.		Light intensity in foot candles.
	Cent.	Fahr.	
Boltonia asteroides .. .. (False starwort)	25	79	268
Pisum sativum .. .. (Common Pea)	14	57	113
Silene latifola .. .. .. (Virety of Silene (Campion Catchfly))	25	79	226
Lactuca scarivca .. .. (Prickly lettuce)	25	79	254–381
Erigeron canadensis .. .. (Horse weed)	25	79	293
Melilotus alba .. .. .. (Melilot white)	14	57	333
Phaseolus vulgaris .. .. (Haricot Bean)	25	79	240
Stellaria media .. .. (Stitchwort)	25	79	259
Avena sativa .. .. .. (Common oats)	14	57	268
Hordeum vulgare .. .. (Barley)	14	57	183–226

TABLE XXI. (*contd.*)

Plant.	Temperature.		Light intensity in foot candles.
	Cent.	Fahr.	
Secale cereale (Rye)	14	57	170–340
Triticum vulgare (Kota) (Wheat)	14	57	183–226
Triticum vulgare (Winter) (Wheat)	14	57	183–226
Triticum vulgare (Bluestem) (Wheat)	14	57	183–226
Triticum durum (Monad) (S. Europe) Wheat	14	57	183–226
Raphanus sativus (Radish)	14	57	395
Trifolium pratense (Clover)	14	57	395
Melilotus officinalis (Melilot)	14	57	395
Viola Tricolor (Wild Pansy)	25	79	282
Tropaeolum minus (Nasturtium, Peru)	20	68	71–127
Oxybaphus nyctagineus (Umbrellawort, N. America)	20	68	381
Cucurbita moschata (Musk Melon)	20	68	71–141
Linum usitatissimum (Flax)	20	68	141–296
Nicotiana tabacum (Tobacco plant)	20–25	68–79	226–2829
Zea Mays (Maize or Indian Corn)	25	79	141–846
Euphorbia splendens (Spurge)	20	68	226

TABLE XXI. (*contd.*)

Plant.	Temperature.		Light intensity in foot candles.
	Cent.	Fahr.	
Lilium longifolium .. .. (W. Lily Longleaf)	20	68	338
Salvia sp. .. .. .. (Sage)	20	68	85
Pelargonium sp. .. .. (Storks Bill)	20	68	99–155
Trifolium hybridum .. .. (Clover)	20	68	113–170
Chenopodium album .. .. (Goosefoot)	20	68	141–2998
Amaranthus retroflexus .. (Love-lies-Bleeding)	20	68	141–2998
Solanum nigrum .. .. (Nightshade)	20	68	211
Cannibis sativa .. .. .. (Hemp)	20	68	85-127
Dianthus barbatus .. .. (Sweet William)	20	68	183
Fragaria sp. .. .. .. (Strawberry)	20	68	423–566
Cucumis melo .. .. .. (Melon)	20	68	141–566
Fagopyrum esculentum .. (Buck wheat)	20	68	85–113
Hibiscus trionum .. .. (Bladder Ketmia)	25	79	170–254
Solanum tuberosum .. .. (Potato)	25	79	127–141
Curcurbita Pepo .. .. (Pumpkin)	25	79	141–211
Aster sp. .. .. .. (Starworts)	25	79	141–566

The effects of duration of light have been summarised by Garner and Allard in the United States. They have classified plants into three groups, (a) long day plants, requiring a day of 12 hours or more and hence blooming in the summer; (b) short day plants, which bloom in early spring or late autumn when the light and temperature have diminished somewhat: (c) intermediate plants which will bloom all the year round since all lengths of day are suitable for them. It is evident, for instance, that no good can be expected by lighting a plant of the short day type, such as a chrysanthemum.

Tests seem to indicate that it is the longer waves of the spectrum which have the greatest stimulating effect, if the temperature is kept down. The shortest waves can be screened off without any noticeable results. This is to be expected since the green chlorophyll pigment reflects the short wave green and violet light, and only light absorbed can have any effect.

Increasing the amount of carbon dioxide in the atmosphere gives more rapid growth up to a point, as Tjebees and Uphof discovered in 1921. In some experiments where the effect of an unscreened gas-filled lamp was compared with the effect of the same lamp screened with coloured glass, a poorer growth with the unscreened lamp was traced to the fact that the temperature was too high. It is often apparently an advantage to interpose a thickness of water of about half an inch between the lamp and the plants, to absorb some of the excess heat.

At the Paris Exhibition of 1900, the writer had the opportunity of inspecting the effects of electric lighting on plants through glass of various colours and then again in 1906 he was privileged to observe the experiments at Schenectady carried out by Dr. Steinmetz with mercury vapour lamps. Until the last few years most work in connection with the artificial illumination of plants has been carried out with light of ordinary intensity, but mention must be made of some very interesting work which has been done by Dr. R. B. Harvey, of Minnesota, on the growth of plants entirely in artificial light. Many plants were grown from seed to seed in the continuous light obtained from 200 watt and 1,000 watt nitrogen filled Mazda lamps, used, of course, in conjunction with suitable reflectors.

Dr. Harvey used good soil for all his experiments and occasionally watered the plants with Knop's nutrient solution, so that there should be no deficiency in mineral nutrients. The light intensity, he measured by means of a Macbeth illuminometer, and by placing the plants at different distances from the lamps, he managed to arrange that each obtained the correct intensity. He noticed that plants grown at a wrong intensity were likely to become weedy in appearance. His experiments with Easter Lilies showed that with continuous artificial light, these can be made to bloom within two months after sprouting, that is to say, a month in advance of the same type of bulb in the ordinary greenhouse; the intensity of light upon them was as high as 1,200 foot-candles, the constant temperature being 68 deg. Fahr. (20 deg. Cent.). Nasturtiums, it was discovered, kept longer, as these plants contain much more than the normal amount of sugar.

Minnesota is not the only agricultural experimental station in the United States, where artificial light experiments are being carried out. Experimental work in this branch of science is being carried on in at least a dozen States.

In New York City, at the Boyce Thomson Institute, for Plant Research, in Yonkers, two basement rooms are used for experimental work. There is no day-light in either room. One is kept consistently dark and serves as an artificial night. The other is illuminated by powerful electric lights suspended from the ceiling. Healthy plants have been reared, though their whole life has been passed in one or other of these two rooms. In fact, the conditions obtained by a wise interchange of artificial light and artificial darkness are superior to the best greenhouse or natural conditions, in the case of such plants as geraniums, snap dragons, radish, sun-flowers and sweet peas.

The main effect which these particular experiments prove is that artificial light can be substituted for ordinary light, in fact, that it is superior to normal light. Further experiments have been carried out with the idea of discovering what would happen if day-light were supplemented by electric light at night. In a large greenhouse, forty-eight electric lights of 1,000 watts each, were installed, the lamps being arranged so that the amount

of light used could be regulated. The process was found greatly to hasten the growth of the plants. Sweet peas bloomed five weeks earlier than would otherwise have been the case. Lettuce growth was expedited by something between a fortnight and a month, and, most remarkable of all, a certain type of clover which under natural conditions takes two years to bloom, was brought to flower in a little over two months.

The author decided to carry out some work of this kind in his own greenhouse, more particularly to ascertain if there were likely to be any commercial advantages in intensive lighting. For this purpose he employed 1,000 watt Mazda lamps and giant reflectors of 2 feet in diameter.

It has always been assumed that ultra-violet rays are an important factor in plant growth, hence many experimenters have used mercury vapour lamps, rather than the gas-filled lamps employed by the author. A test of the gas-filled lamps made by the writer, shows that though they provide hardly any trace of ultra-violet light, yet there is no doubt that they have been and are most efficient in hastening the growth of the plants beneath their influence. This suggests to one that, after all, ultra-violet light is not so wonderfully beneficial to plant life as one is always led to believe it to be. In this connection it should also be mentioned that the constitution of the window glass of the ordinary greenhouse is such that it cuts off all ultra-violet light. The heating apparatus of the greenhouse nullifies the ill effect of the absence of these ultra-violet rays.

For experimental purposes, in the greenhouse of the author, a self-winding automatic time switch was installed, which controlled the lights, and it was found convenient to arrange for the electrical treatment to be given to the plants between midnight and 6 a.m. as during this period the current was not required for anything else. From the point of view of the current consumed, the work done to date has shown that electrical treatment by intensive illumination is at present a costly process, except for the special purposes to which reference is made a little later. Should the treatment be sufficient, there does not seem to be any reason why Power Supply Companies could not give special rates during the night hours. Further, the

rearing of flowers in winter is a luxury trade, for which the purchaser expects to pay heavily, so that the question of cost is not at all times of primary importance. Nor does it enter into the calculations when the object of the treatment is for purposes of seed breeding.

Fig. 97.—The plants when first subjected to intensive electrical illumination.

The plants under test (Figs. 97 and 98) included daffodils, lent lilies, narcissi, lettuce and a variety of other plants, similar control plants were placed in another part of the greenhouse, so that the relative speed of their maturity could be accurately gauged. In the case of the bulbs above mentioned,

the plants were placed under the light when the buds were just beginning to form. Daffodils, and Lent Lilies, flowered in four days, growing about ¾ inch per day. Narcissi flowered in seven days. An azalea plant in full bud opened to full flower in one night.

Two discoveries made by the author combine to make the commercial side of this process better than would at first appear.

Fig. 98.—The plants after four night's treatment.

In the first place it is not necessary to give plants six hours continuous treatment every night. Relatively, the progress made is considerably greater if plants are given one night's treatment, than if they are given six, so the suggestion is made that the market gardener should treat his plants in this way

if he wishes to obtain the best possible advantages from the use of electric illumination.

To avoid the trouble of moving the plants from one side to another of the greenhouse, it is suggested that the lamps should be suspended from an over-head run-way of galvanised wire. In that way, lamps can be moved from section to section of the greenhouse. The second use to which the market gardener can put electric illumination is in the matter of the treatment of seedlings. Transplanting acts as a check on the growth of plants and a check on anything young takes a lot of making up. In fact, the day after this transplanting operation has been performed, every gardener knows that the seedlings frequently fall over and wilt. If, immediately after transplanting, the seedlings are exposed to one night's intensive illumination treatment, they will be found to be strong and healthy in appearance on the next day, instead of suffering from the ill effects of their transplanting.

Electrical forcing by intensive light is far preferable to forcing by any other means, for whereas when forced by other methods, blooms frequently are found to loose colour quickly, but in the case of electrical forcing, the colour does not appear to be in any way effected.

Electrical Pollination.

The creation of new varieties of plant life.

In Italy the Italian Government has combined with electrical firms in the establishment of a laboratory at Pistoia. Here, through the action of an electrical discharge on the pollen it is claimed that it is possible to produce new varieties of vegetables. Photographs show that the electro-culturist can by this means change the colour, size and shape of such fruits as tomatoes, marrows, sunflowers, cabbages, etc. Herein lies a field of work which as yet has been very little explored.

The Electric Heating of Greenhouses.

Where power can be obtained very cheaply, the electric heating of greenhouses is obviously more simple and satisfactory than heating of any other kind. Recently the author had the opportunity of investigating some greenhouses which were elec-

trically heated. The special problems of the greenhouse required slight modifications on ordinary heating practice. For instance, the air is moist and therefore the totally enclosed iron-clad type of switch must be used.

Effective distribution of heat can be obtained by the employment of bare wires running round the greenhouse, but these wires must have some protection from water drippings from plants overhead.

Heating the Soil.

In contrast to the traditional idea of heating the greenhouse, there is also the method pursued by Director Hjalmar Olsen (Norway), who heats the soil by means of laying an electric heating cable at a depth of sixteen to eighteen inches beneath the level of the ground. Excellent results have been obtained by this means. A similar installation has been made in the author's garden.

An interesting suggestion for the heating of the ground, was put forward by Mr. H. M. Sayers at a meeting of the Institution of Electrical Engineers last year. It was to the effect that the waste heated water from a central station supply should be directed through buried pipes to warm the soil above them for the purposes of defeating the ill effects of spring frosts, etc.

Electricity for the destruction of pests.

This is a matter which is at present entirely in an experimental stage. Periodically it is claimed that extermination of pests by electricity is a practical proposition. A high tension discharge as used for electro-culture over plants certainly causes the wings of certain insects, owing to the electro-static effect, to extend towards the source of the charge. This makes the insects loose their balance, fall to the ground and become a prey to their enemies. With valuable plants, almost actual contact with high tension current has been tried, and, as might be expected, any insect coming in the path of the spark is destroyed. This naturally involves too much labour.

In Washington, U.S.A., wires are being strung through apple trees, over which a powerful electric current is to be passed in the hope of exterminating the codling moth. In the rose

gardens and cherry orchards of Seattle this experiment has already been made with a certain amount of success, hence the extension of the idea upon a larger scale. In Egypt a form of harrow, electrically charged, has been drawn over the ground for the purpose of killing locusts. This has been successful, but difficult to accomplish on a large scale.

Moth catching traps in Virginia are placed three to an acre at about ten feet from the ground. A reflector is placed over the light to prevent water dripping into the trap-pan. The latter holds three quarts of paraffin and is supported from the reflector by four wires at about six inches under the lamp. Whenever a moth flies against a light, it drops, hence if a liquid that will kill it is placed directly under the lamp it will be caught.

It costs £180 to wire thirty-two acres (ninety-six lamps). The current consumption costs twenty-one shillings per night during the moth season. The killing of the moths means an extra profit of £400 to £800 a year on tomatoes.

In Ontario, fruit growers are following the example of contemporaries in New Jersey by equipping their orchards with electric lamps. These are hung fairly near the ground and beneath each one a large pan of paraffin oil or other liquid is placed. After dark when the lamps are alight, the oriental peach moth and other insects fly to the light, become dazzled by it and fall into the liquid below. A similar method has also been tried in Japan.

A death ray for the destruction of insect pests has been developed in America. It is produced by a powerful electrical discharge inside a glass vacuum tube at one end of which there is a window of aluminium, through which moving electrons pass. The ray has an effective range of eighteen inches, and up to date it is reported that it has been used to kill bacteria spores (with an exposure of one-tenth of a second) and fruit flies. This, however, is another matter that obviously requires a good deal more investigation.

Mr. Carr Bennett has claimed that his system of electrical treatment of seeds helps in the extermination of weeds because electrified seed has been given a start and is always so much in advance of the weeds that they never catch up with it, i.e., they never choke the plant.

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CHAPTER XV.

IRRIGATION, PUMPING AND LIQUID MANURE DISTRIBUTION.

Decimal Class. 631.7E

A very important question in many parts of the World is the provision of an adequate water supply for the irrigation of crops, and to make them independent of the vagaries of nature. No new principles are involved, except that electric motors are now employed to operate the pumps in place of windmills and various types of heat engines. The gradual ousting of all other forms of prime mover, in favour of electricity, is due to the fact that the pumping is nearly always required at some distance from convenient places for the power stations and at times when it is often inconvenient to operate other prime movers. Electric motors are also so much more conveniently handled by unskilled staff. Further they may be automatically started and stopped, or controlled from remote positions.

On many farms abroad where water is available, it is being employed for irrigation in seasons of low rainfall. In this way the farmer has another aid in circumventing the weather, as he is able to regulate the supply of water at the period when plants require it most, which is at the time of maximum growth. Before the advent of electric pumping, any such scheme was not really practical on account of the labour and capital costs necessarily involved.

It is a very interesting point, demonstrated by experience, that the limiting cost per acre for irrigation for general farming (as distinguished from intensive farming) is five shillings per annum for wheat lands, and fifteen shillings for sugar cane. So if the pumping costs and interest charges exceed this figure, the scheme is doomed to failure as a commercial proposition.

Five hundred to seven hundred gallons of water per minute is the minimum sufficient to irrigate one hundred acres. Each irrigation usually varies from two inches to six inches deep (chiefly about two inches) with say a total of two acre-feet per acre per annum, or say 550,000 gallons per acre per annum, depending, of course, upon the locality. It may be reckoned that twenty per cent. of the water pumped will be lost by seepage and evaporation. There are six main methods of applying water to the land, viz.: —

(a) vertical distributing stand-pipes of large diameter, fed by underground pipes.
(b) portable 12 ft. galvanised light steel pipes.
(c) blocking or checking in sections.
(d) general flooding.
(e) distribution in furrows.
(f) spraying method (either with or without portable rolling pipes).

In certain countries such as the Netherlands, very large electric pumping installations are now in operation for the removal of excess water. Electric pumps are rapidly replacing windmill pumps, even in flat countries such as Denmark and Holland, on account of their greater reliability and the fact that pumping is nearly always required during periods of rain, when there is no wind. An interesting development of irrigational farming is the maintenance of the water level in the fields at definite depths below the surface, in accordance with the nature of the crops. The depth of water in each field or range of fields is controlled by automatic electric pumps.

In the Shesta Valley in California an annual harvest valued at over £100,000 ($480,000) is obtained from land irrigated entirely by electrically driven pumps. In certain parts of the States of Oregon and Idaho there are a number of electric pumping equipments which elevate the water as high as 100 ft., and irrigate 1,500 acres of land. In two prefectures in Japan there are installed 1,990 electric motors, with a total capacity of over 1,700 horse-power, for irrigating the land. In Japan it has been found that one small electric motor can irrigate ten acres of land and take the place of 200 men-days during ordinary

seasons and 320 men-days in dry seasons. By means of the electric motor, large tracts of land hitherto unsuitable for any purpose have been converted into profitable and productive areas. The electric motor has simplified irrigation, as it is so much more reliable than other means of power and can also be run for weeks at a time without stopping. In fact, there are a number of electric motor irrigation installations operating for twenty-four hours a day for five months of the year, the only attention they require being occasional oiling of the bearings. In Germany there are over 4,000 automatic watering or spraying plants, in use in market gardens and farms. (Fig. 99).

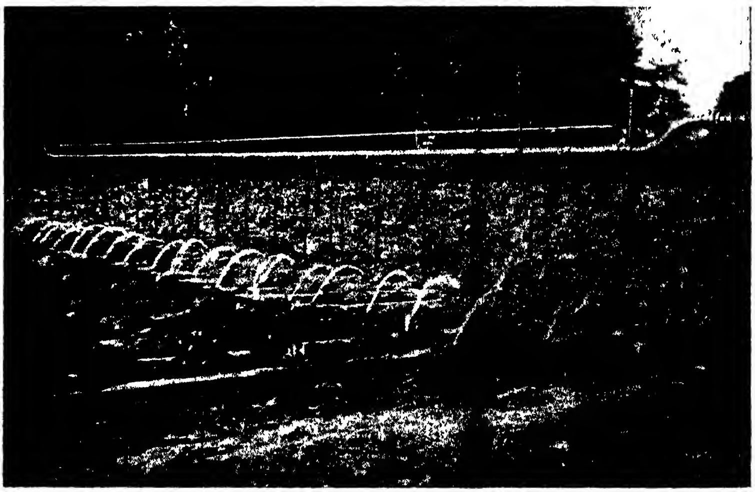

Fig. 99.—Rain and sprinkler carriage.

Central Manuring Plants.

The manuring of a number of Swiss fruit farms is now done by means of stand pipes in the orchards. These pipes are connected by underground mains to a tank, fixed near the main buildings, in which is collected the urine from the cowsheds. When the stand pipes are to be used, old rotted manure is thrown into the tank, the contents being agitated by means of electric motors, either by driving revolving arms or by circulation through centrifugal pumps. A force pump, taking its supply

from this tank, pumps out the mixture to the stand pipes in the orchard, from which the liquid is distributed by a hose pipe and nozzle.

This system has been found to save so much labour, both of horses and men, that it is becoming a general farm practice in many parts of Switzerland. As the distribution pipes are laid about three feet in the ground comparatively cheap pipes can be employed, which greatly reduces the cost of the installation. Further, the uniformity of the mixture helps to produce uniform fertility of the soil.

Fig. 100.—Directing a powerful jet of water to wash the straw in a manure pit.

The mains thus used for manuring the fields with liquid manure can, of course, also be employed for watering them in exceptional seasons of drought. The consumption of electric current for liquid-manuring and watering in accordance with this process amounts to ninety units per acre, and is therefore an attractive load from the point of view of an electricity supply undertaking. A more recent development is where the manure is placed daily in a shallow pit, about one foot in depth, and

then played upon with a powerful jet of water directed by a man with a hose pipe, so as to wash the straw, the liquid being allowed to run away to an underground storage tank. (Fig. 100). By means of a centrifugal pump the water is supplied to the jet at a very high pressure. The liquid in the underground

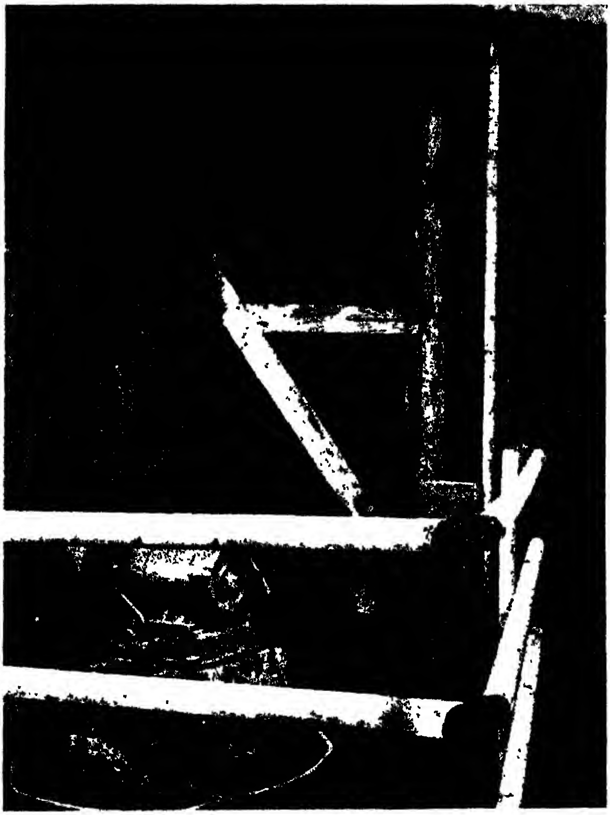

Fig. 101.—Electric motor attached to liquid manure pump at Greater Folcourt.

tank is stirred and agitated by means of an electrically driven centrifugal pump, another centrifugal pump delivers the liquid through cast-iron pipes laid in the ground to various points on the fields, where hose stand pipes are provided. The liquid

manure is distributed over the fields by means of a hose pipe. While these installations were originally started for market gardens, they have now been found very advantageous for ordinary farms, as the manure is dealt with hydraulically, except the short delivery from the cowhouse to the washing pit. The distribution is also carried out hydraulically, thus saving carts

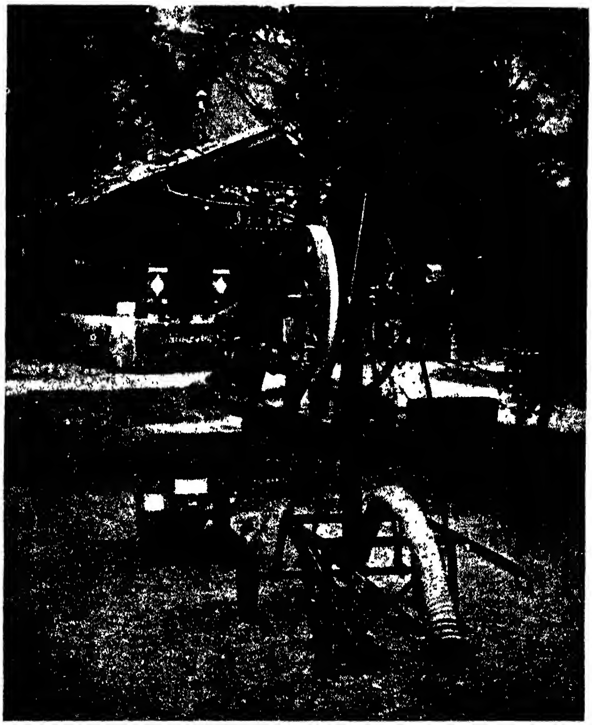

Fig. 102.—Manure pump driven by portable motor.

and horses and men's time, as one man with a hose pipe can accomplish as much work as a couple of teams of horses and several men could by the old method. The washed straw from the shallow pit is put aside in a heap to rot in the usual way. Fig. 101 shows the liquid manure pump installed on the author's farm, while Fig. 102 shows a portable motor attached to a portable liquid manure pump.

Water Supply for Farm House and Buildings.

Electric motor pumps which provide the farm with a water system for the home and buildings are one of the most highly prized advantages claimed by those who have adopted them. One of the greatest hardships on an average farm is the continual carrying of water, a task which often falls on the women folk. The burden of this task can be better realised by investigating the amount of water required on the average farm. The minimum requirement for the average mixed farm of say, 150 acres, is 600 gallons per day. The time required for one man to pump this amount, with the most efficient hand pump would be thirty minutes. Table XXII. shows the usual amount of water required in villages and farms and a casual perusal of this table should demonstrate the great need and advantages of using the electric motor.

A further advantage of a running supply of fresh water is that in the case of dairy cows it is an established fact that a constant supply of fresh clean water results in a higher milk yield and a cow will drink far more water when it is fresh, pure and always available near the feeding trough. Incidentally, the new Milk and Dairies Act, has for the first time made the cooling of milk to a specific temperature compulsory, therefore the need of a constant supply of fresh water in the dairy is absolutely essential.

Automatic attachments can now be obtained for operating the pumps. The most usual form is where an attachment is provided in the storage tank, which, when the water falls below a certain level, starts the motor and directly it rises to the predetermined level stops it.

When installing a new water system it is as well to employ a high pressure one, as buckets, etc., are naturally filled more quickly, if the supply is provided at a pressure of about 40 lbs. per square inch (280 kg. per sq. dm.). An air pressure storage tank is employed to provide the necessary pressure. As a rule only a fractional horse-power motor is required.

Table XXII.

USUAL WATER SUPPLY REQUIRED IN VILLAGES AND ON FARMS.

1,400 gallons per day for a small country house with stables and garden.

4,500 gallons per day for a mansion with stables and garden.

600 gallons per day for the buildings on a 150 acre farm.

210 gallons per day for a small dwelling house with six inmates having one bathroom, no stables or garden.

60 gallons per day for a small cottage.

15 gallons per day per person for village supplies where taps are fixed in all houses.

10 gallons per day per person for village supplies where the water supply is not taken into the houses.

50 gallons per day per motor car.

On the Farm.

25 gallons per person per day.

25 gallons per dairy cow per day.

15 gallons per head of cattle per day.

15 gallons per horse per day.

2 gallons per pig per day.

$1\frac{3}{4}$ gallons per sheep per day.

Pumping Water.

To pump 1,000 gallons of water to a maximum height of 15 feet takes one man 15 minutes, one horse 7 minutes, and a 1 horse-power electric motor $4\frac{1}{2}$ minutes.

To pump 1,000 gallons of water to a maximum height of 50 feet takes one man two hours 48 minutes, one horse $23\frac{1}{2}$ minutes, and a 1 horse-power electric motor 15 minutes.

To pump 1,000 gallons of water to a maximum height of 100 feet takes one man 5 hours 36 minutes, one horse 47 minutes, and a 1 horse-power electric motor 30 minutes.

To pump 1,000 gallons of water to a maximum height of 200 feet takes one man 11 hours 12 minutes, one horse 1 hour 34 minutes, and a 1 horse-power electric motor 60 minutes.

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CHAPTER XVI.

ELECTRICITY ON THE POULTRY FARM.

Decimal Class. 636 5E

TABLE XXIII.

USES OF ELECTRICITY ON POULTRY FARMS.

Egg tester.
Incubators.
Fans for circulating air in incubators.
Ultra-Violet Ray Treatment.
High Tension treatment.
Ozone treatment of growing stock and poultry houses.
Hovers and foster mothers.
Light in laying houses (to increase egg production).
Automatic time switches.
Pumps.
Water boilers.
Drinking water heaters.
Grain sprouters for oats.
Food mixing machines.
Bone grinders.
Green bone cutters.
Grain crushers.
Grinders.
Kibblers.
Grist mills.
Chaff cutters.
Greenstuff cutters.
Grindstones.
Whitewashing machines.

Economic Considerations.

Undoubtedly one of the main factors necessary for poultry farming is based upon the reduction of the labour cost per bird to as low a figure as possible. One of the ways of attaining this aim is to employ electricity as a medium for power. At the same time advantage can be taken of it for purposes of lighting and special treatment. This possibility of being able to utilise

Fig. 103.—Egg testing by means of an electric hand lamp.

electricity for a number of purposes is a very attractive feature, but is not, of course, in itself a sufficient argument. Experience as regards the use of electricity on poultry farms in this country, is not at present as widely spread as it should be. The author's own poultry farm is equipped with electricity, and he is aware of about fifty other installations. In America, however, electricity is used on nearly all large poultry farms, and has proved highly beneficial and economical. There is

really no reason why it should not be, for that is the experience of every other industry. Electricity is generally utilised by these industries, not because it is electricity, but because it is the most convenient and efficient means of transmitting power from the generating plant to the machine which it is required to drive. Further, it is a form of power that can be utilised

Fig. 104.—Testing trays of eggs by means of an egg testing table.

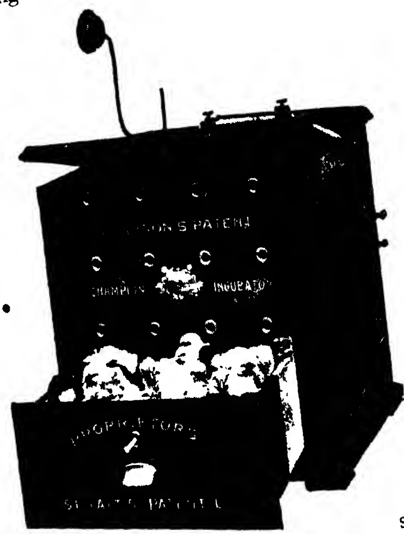
so conveniently—a twitch of the switch and an electric motor starts up without the great amount of trouble that is associated with independent oil engines, long lines of shafting, hydraulic systems, etc.

Electricity is, of course, a science in itself that requires considerable study. However, the requirements of the poultry

farmer are specialised and simple, so that what he has to know is easily acquired.

Testing Eggs.

The electric lamp is, of course, ideal for this purpose, as it is so easily switched on and off and provides such a powerful source of light. (Fig. 103). The electric tester consists of a metal case, usually white enamelled, containing an electric lamp and having an oval, felt-lined opening rather less than the



Spratts, Ltd.

Fig. 105.—Hearson Electric Incubator.

size of an egg. There is also a larger tester for the use of large poultry farms. This consists of a metal table with a slot right across the surface, through this slot the light of five or more 60 candle-power lamps is reflected. (Fig. 104). The tray of eggs to be tested is placed over the slot and the operator is able to test an entire row at one time. In another form, the tray is provided with a circular hole for each egg. In a refinement, the condenser of a magic lantern is employed to pass a powerful, concentrated beam of light through the egg.

Incubators.

In the field of artificial incubation first place must be given to the electric incubator. Owing to the practically constant voltage of the normal electric supply, the temperature of incubators can be regulated more accurately by the aid of electric heaters than by any other means. (Fig. 105).

A number of methods are employed for constructing the electric heating element. One method is by winding a very

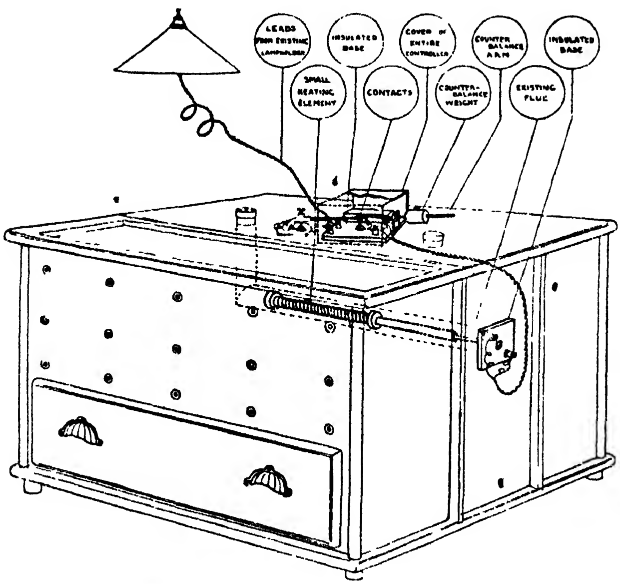


Fig. 106.—Method of converting an oil lamp incubator into an electric one.

fine bare resistance wire in a number of sections and placing these so that they cover the whole surface of the egg tray, thereby diffusing a gentle heat evenly over the whole area. The sections are connected to an automatic regulator, and when sufficient heat is obtained the sections are cut off, one at a time, automatically. This means a great saving of current, because when the hatch progresses, animal heat is given off, which can be used instead of the applied heat.

In all cases only the current necessary to maintain the temperature is consumed, once the desired degree of heat has been reached. A further advantage of an electric incubator is that a small lamp can be inserted inside the lid near the thermometer, making the night reading of the thermometer and general inspection a simple matter. Another type of electric incubator is so designed that should the current be temporarily cut off, no harm will be done to the hatch, because sufficient heat is stored in a water jacket, which surrounds the heating element, to keep the incubator up to its correct temperature for some time. As a matter of fact, as shown by a number of experiments, in a well lagged incubator, no difference in the result of the hatch can be observed, if the current should be cut off for twelve hours or so, during the period of incubation. It is reasonable to expect this, for after all the hen often leaves her nest for a while.

Existing oil lamp incubators can easily be converted into electrical ones, by inserting an electric heater as shown in Fig. 106. The Gloucester Incubator Co. manufacture a dual purpose incubator, which can be operated by electricity or oil. The complete electric element can be removed from the heater and a spare flue suitable for oil consumption substituted in a few moments.

There is also a type of electric incubator which produces the necessary heat by means of ordinary electric light bulbs. This type is of interest as it is claimed (though it is open to doubt) that the light invigorates the developing embryo.

The outstanding advantages of electric incubators as compared with all others may be summarised as follows :—

(1) Simplicity of operation—the heat is turned on by simply twitching a switch.
(2) The heat is always under perfect control.
(3) The air always retains its life giving oxygen.
(4) No smoke, soot, fumes or smell.
(5) Fireproof.
(6) Can be used anywhere.
(7) Requires no attention night or day.
(8) Produces more sound, healthy chicks (which pay for a lot of heating current).

What is probably the largest electric hatchery in the World, is at Petaluma, California, in which there are electric incubators having a capacity of 604,800 eggs. This is an exclusive electric hatchery. Approximately three-quarters of a million feet of resistance wire were used to produce the heating elements. The current is supplied to the premises at 4,400 volts and there transformed to 110 volts. The switch-board is equipped with two large switches of 1,200 amperes each, twenty-two of 200 amperes, and four of 100 amperes.

Fig. 108.—A mammoth electric fan operated incubator containing 2,400 eggs, in use at Greater Felcourt.

A new electric incubator with a capacity of 2,400 eggs, which could be connected up to an ordinary wall plug, was recently exhibited in New York It had a novel arrangement for turning the eggs so that by pressing a button all the eggs could be turned in two seconds. A new French electric incubator carries the eggs on a continuously moving horizontal tray.

Another great advance in incubator construction is the employment of electric fans for circulating the air inside the apparatus. An electric fan operated incubator occupies a com-

paratively small space, 8 ft. 6 ins. cube being sufficient for a machine with a capacity of 10,000 eggs; while a space 5 ft. square and 32 ins. deep, is sufficient for a 2,400 egg machine. (Fig. 108). This compactness means a big saving in building construction and in attendance, as usually, long mammoth incubators of the same capacity require not less than seven times the ground space, plus the additional room required to operate the incubator on all sides. The success of an electric fan operated incubator lies in the equal distribution of heat and uniform

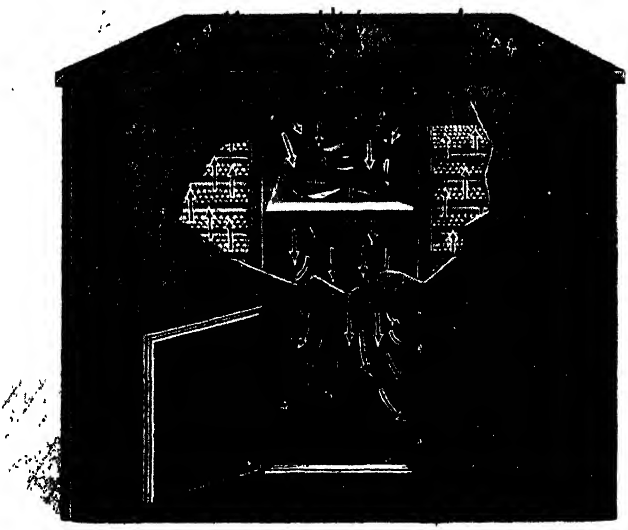


Fig. 109.—Electric fan type incubator showing the system of air circulation.

ventilation. Its small dimensions are due to the fact that the eggs can be placed in several trays, one above the other, which is impracticable in the ordinary stagnant air incubators.

The employment of electric fans forces the warmed air into every part of the egg chamber, keeping every compartment at the correct temperature. In fact, this system ensures that every egg is kept at the same temperature, a condition which is seldom approximated in any incubator of the single tray type.

A supply of fresh air is drawn from outside the incubator through carefully adjusted openings located round the fans; the fans are placed at the top of the heating chamber with the spindle in a vertical position (Fig. 109), so that the fan can force the air downward through the heater coils into the incubation chambers, and thence upward through the egg trays.

Fig. 110.—The bi-weekly hatch at a large poultry farm.

These egg trays are placed in five to ten tiers one above the other. Outlets are provided in the top of the incubator above the egg trays, and through these openings, a certain portion of the air escapes to be replaced by fresh air drawn from the room. This system overcomes the difficulty of securing ventila-

tion without excessive evaporation, which is a common defect in most incubators. Too rapid evaporation results in small hatches and weakly chicks. For successful incubator practice, three vital factors, heat, ventilation and moisture must be automatically held in correct balance.

Eggs that are incubated in machines of the ordinary type have to be taken out of the apparatus and cooled once or twice every twenty-four hours; but under the electric fan system, the eggs require absolutely no cooling, as of course they

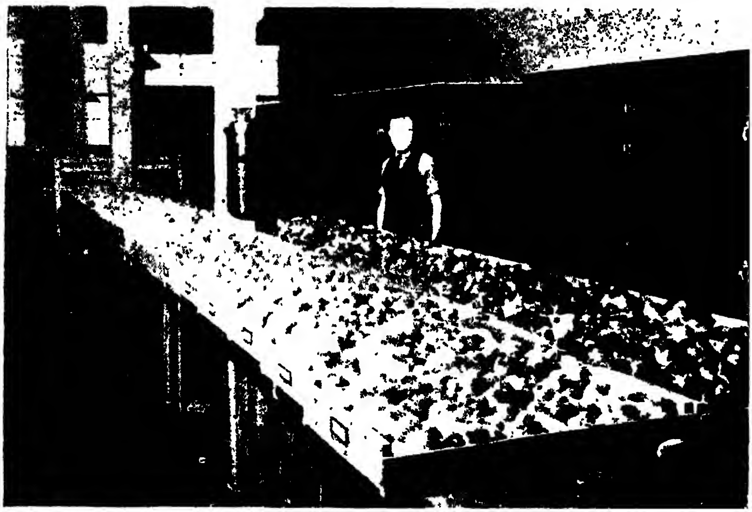


Fig. 111.—Day-old chicks straight from the electric incubator.

are not confined in a closed compartment, in which the circulation of air is necessarily both slow and sluggish.

Incidentally, one of the attractive features of the electric fan incubator lies in its ability to permit of continuous hatching, that is, the trays are filled in turn and hatch in turn, and also it is found that the chicks hatch out regularly in the same number of days, which fact is again due to ideal conditions of heating and ventilation. (Figs. 110 and 111).

On the author's farm, the hatching efficiency over two years was 83.5 per cent., truly a high figure when it is considered

that attention is reduced to two inspections per day, all cooling of eggs being eliminated, while the turning is done in five minutes. This high efficiency is not an exceptional case as the majority of the users of this type of machine claim an 80 per cent. to 88 per cent. hatch of all fertile eggs, and above all, the chicks hatched are healthier and stronger. A minor but not unimportant point is, that only one regulator and two thermometers are required for an incubator with a capacity of 10,000 eggs, as compared with the 74 or more regulators and a similar number of thermometers, necessary in the ordinary mammoth incubators.

The amount of current required to operate an electric incubator is shown in Table XXIV.

TABLE XXIV.

Size of Incubator.	Voltage.	Watts.	Consumption per hatch in Units (kWh). Current cut off 60 per cent. of the time.
65-egg	110	75	15
150-egg	110	100	20
300-egg	110	200	40
600-egg	110	400	80
65-egg	220	88	17.6
150-egg	220	110	22.18
300-egg	220	220	44.35
600-egg	220	440	88.70

Hovers and Foster Mothers.

Electric hovers are of two types. One using a resistance as a heating element and the other employing electric lamps. Both types have a number of advantages over the older methods, chief among them being the even distribution of heat, which is such an easy matter electrically, owing to the simplicity of distributing the heating elements around the hover, whereas,

with the older types of oil and coal burners, a central heat was all that was possible. The advantage of this distribution of heat is that it prevents the chicks crowding together, trampling and suffocating each other, in their effort to keep warm.

To get a clear, fresh atmosphere is also a difficult matter when using coal or oil, but electric heating allows the chicks to breathe pure fresh air all the time, as there are no fumes or smoke to contaminate the atmosphere.

Fig 112.—One the forty-two compartments in the Author's large brooder house tor 3,400 chicks.

The successful experiments, recently carried out in California, with an electric heater placed around a room (instead of centrally in it, as is customary) large enough to hold over 1,000 chicks will probably lead to a more general use of this method.

A large scale commercial brooder house, recently designed and erected by the author for his farm, comprises forty-two compartments each holding seventy-five chicks. (Fig. 112). In the centre of each, a hot water heated air-radiator is placed. These radiators are now being adapted for conversion into

electric heaters. So successful have they been that the losses have never exceeded 14 per cent.

The amount of current required to operate an electric brooder is shown in Table XXV.

TABLE XXV.

Size of Brooder.	Voltage.	Watts.	Consumption per month in Units (kWh). (Current cut off 50 per cent. of the time).
150-chick	110	220	79
500-chick	110	330	118.8
150-chick	220	220	79
500-chick	220	330	118.8

Ultra-Violet Ray Treatment.

A very promising field for the use of electricity, is the application of ultra-violet rays for hens and chicks. Though more experimental work must be done, there is sufficient evidence to show that there are great possibilities along these lines. Tests, with a mercury vapour lamp were recently carried out at the Agricultural College of Wisconsin, with the result that hens—admittedly not of a high egg-laying strain—treated with a ten-minute ultra-violet radiation per day, laid considerably more eggs than a part of the same flock treated under exactly similar conditions, though not exposed to the rays. (Fig. 113). The effect of ultra-violet rays has also been successfully tried on chicks, producing strong vigorous birds, which at nine weeks old weighed twice as much as chickens of the same age not subjected to treatment. The author himself has not as yet corroborated these tests, though he intends to do so at the first opportunity. However, he has been carefully studying the effect of ultra-violet rays on human beings and has carried out experiments with these rays on plants since 1906. The most

advantageous period to apply the treatment seems to be during the months of December, January, February and March, for early chicks suffer from lack of sunshine under the best conditions and the small amount of sunshine that they do receive during the winter usually passes through ordinary lead or soda glass which only too effectively screens off the valuable ultra-violet rays of the sun.

There are three principal methods of providing ultra-violet rays: (1) By using a special window glass which is transparent

Fig. 113.—Hens being treated with Ultra Violet Rays.

to ultra-violet rays; (2) by means of a vacuum or gas-filled lamp made of glass, which permits of the passage of the rays; (3) by means of a mercury-vapour lamp (Fig. 114); and (4) by means of an arc lamp, using suitable carbons. (Fig. 115). When tungsten rods or cored carbons are employed in the arc lamps, a much greater efficiency in ultra-violet light production is obtained. It is now generally believed that black-feathered poultry do not gain much benefit from mercury arc lamps, which seems to point to the fact that both fur and feathers serve more or less as a screen.

A special application is now being developed for the treatment of chickens, in which an arc lamp is fixed in a portable frame (somewhat like a small clothes-horse on its side) which can be conveniently placed over the feeding place of the chickens. A piece of special glass which is transparent to ultra-violet rays is interposed between the lamp and the chickens so as to stop any sparks from the arc falling on them. (Fig. 116). Before the feeding takes place, the food is spread thinly over a board and is itself artificially sun-treated for ten minutes or so.

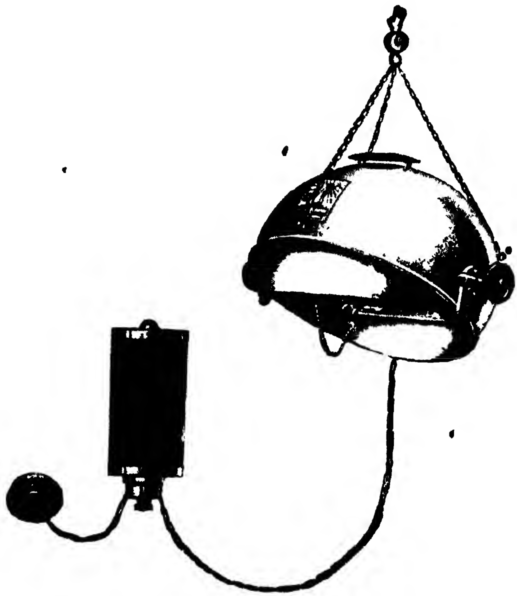


Fig. 114.—Hanovia Mercury Vapour Lamp.

The treatment is given for about ten minutes during the morning and again during the evening. The eyes of the attendant, who is giving the treatment, must always be protected by means of coloured glasses, as the radiations are of grave danger to the eyesight. Too much care cannot be exercised in this respect, as these rays are neither seen nor immediately felt by the human eye, and it is some hours after exposure before

any pain is felt. Fortunately, the eyes of livestock are well protected.

Excellent results have been obtained with chickens by using a specially manufactured glass, which contains a high proportion of quartz and is transparent to the vital rays of the sun, in the windows of the chicken house. Chickens reared under this special glass grow quicker and are more active and develop into finer birds than those not so treated. This is only

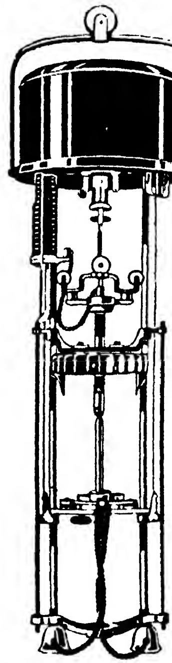


Fig. 115.—Arc Lamp.

to be expected, as in the Spring the cold air and wind keep the chicks indoors for some time after they are born, thus depriving them of the vital part of the sun's rays. When there is no sun, the artificial sunlight arc lamp should be used.

Those who wish to use ultra-violet light lamps, should wire their houses with 7/.064 wire, to carry the heavier current required. A 15-ampere plug in a central position will usually

suffice. A controlling resistance will be required. This can generally be made a fixture to the wall, as then only the lamp itself has to be moved about. An electric pressure of at least fifty volts is required. Where the voltage is one hundred or over, two arc lamps can be economically operated in series.

Fig. 116.—Treating chickens with Ultra-Violet Rays.

Electro-Culture.

This method is even more in the experimental stage than ultra-violet light. The current consumed is so little that it can be taken off any existing lamp socket. The distribution of the electric charge is best attained by means of very fine

aeroplane steel wire (No. 29 gauge) stretched through the brooder house. This wire can be slung on a chain of four wireless type butterfly insulators. A fair-sized opening should be made where this wire has to pass through a wall. Even though the houses are some distance apart there is no appreciable loss in transmitting, since the pressure is high.

The electrical charge can be obtained from a ten inch medical or X-Ray coil, or alternatively, if an alternating current supply is available, from a transformer and a mechanical synchronous electric motor rectifier of the Newton-Wright type. Large wireless valves can also be used for rectification. Rectification is necessary because only uni-directional current is of any use, i.e., the overhead wires must carry a positive charge. Another method, which is extremely simple, is to employ a large number of wireless high tension batteries, in series. These must be supported on insulators. This treatment is given for an hour or so each day, and seems to brace up and stimulate the birds. It seems probable that any good effects are due rather to the purification of the air in the brooder or laying house respectively, by the production of ozone in the corona discharge. It is also quite possible that it assists the birds to relieve themselves of any insect pests; for in the presence of a high tension discharge, it has been discovered that the antennæ, limbs, etc., of small insects become uncontrollable.

A considerable amount of experimental work has been carried out in connection with the applications of ozone and high tension currents to incubators. It is claimed that the breaking through the shells of a hatch is more uniform, i.e., all the chicks come out within ten hours, as compared with the normal range of 20-40 hours.

Young chicks under electric treatment, applied for a few hours daily, attain the size of three months old birds in under nine weeks. Five weeks' old chicks are stated to be ready for market as *petit poussins* as compared with the normal three months.

Lighting of Poultry Houses.

The use of electric light to increase egg production during the winter months, has proved to be one of the most important

organised poultry farm, a poultryman can attend to 1,500 birds and even during the incubating and chick rearing season, deal with some 3,500 chicks in addition, with a little extra help.

Careful investigation seems to indicate that the hens do not lay more eggs per annum, but by the use of artificial lighting, and the consequent longer hours of exercise and feeding, it has been conclusively shown that more eggs are produced at the time they are most in demand. (Fig. 117). After all, the domestic fowl originated from the tropics, where the winter days are longer, and accordingly the digestive and reproductive organs are probably better suited to tropical hours, and those of spring-time. This certainly appears to be the case, as the general health of the birds is not affected in any way. (Fig. 118). Unlike many birds and animals, the eyes of hens are not so constituted as to enable them to see properly in the dark, hence the necessity for artificial light, if the hours of exercise and feeding are to be prolonged during an English winter.

Intensity of Light.

The lighting of poultry houses should not be carried out in any haphazard way. Care and attention must be given to a number of factors which are essential if the maximum efficiency is to be obtained. The main factors are :—

(1) The intensity of the light on the floor should be about a foot candle.

(2) The lamps should be hung about six feet from the floor, so as to allow sufficient head room for the attendant and be out of reach of the birds.

(3) All the rays of light should be reflected on to the feeding space.

(4) Some of the direct rays should strike the perches.

(5) There should be the least possible expenditure of electrical energy.

As the light from an ordinary electric lamp shines out in all directions, it is advisable to place a suitable reflector over it, and so reflect the light in the most useful direction. The author has tested a number of different types of reflectors, and has found that the following are suitable for poultry house work :—(a) The vitreous enamelled dispersive type, (b) the

vitreous enamelled extensive or bowl type, (c) the glass industrial prismatic type, and (d) the plain conical sheet metal reflector, with an aluminium paint reflecting surface. (This type can be home-made by the poultry man at a small cost).

While (d) is much cheaper than the other three, the author has found that the gain in the initial cost is very soon lost in the lower efficiency of the reflector. (b) is preferred by the author. (Fig. 119).

Number of Lamps required in each House.

The following formula should enable any poultryman to calculate the number of light points and the type of lamp needed to meet his particular requirements.

$$\text{No. of lamps required} = \frac{\text{Area of floor} \times 1.5}{x \times \text{Lumens of lamp.}}$$

x is what is known as the co-efficient of utilization and varies according to the type of reflector used and other illumination factors. Table XXVI. gives the value of x for practically all conditions of poultry house lighting, while Table XXVII. gives the lumens per lamp for the different sizes and types of lamps.

TABLE XXVI.

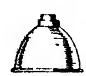
Floor Area	Values of x when using			
	(a) Vitreous enamelled Dispersive type Reflector	(b) Vitreous enamelled Deep bowl type Reflector	(c) Industrial Prismatic Reflector	(d) Enamell'd steelshade Reflector
				
When area of floor is :				
between 80— 130 sq. ft.	.42	.37	.39	.32
,, 140— 200 ,,	.45	.41	.43	.36
,, 210— 340 ,,	.49	.44	.47	.39
,, 350— 600 ,,	.52	.46	.50	.42
,, 600—2100 ,,	.57	.50	.56	.48

TABLE XXVII.

LUMENS PER LAMP FOR DIFFERENT SIZES AND TYPES OF LAMPS.

Watts	Gas-filled lamps		Vacuum lamps	
	Candle-power (Down)	Lumens	Candle-power (Horizontal)	Lumens
25—30 VOLTS :				
30	37	360	—	—
60	69	700	—	—
100—130 VOLTS :				
30	31	275	28	275
40	45	410	38	370
60	75	700	57	550
200—260 VOLTS :				
30	—	—	25	240
40	35	305	35	340
60	60	575	55	547

From the foregoing table it will be observed that there is very little gain in efficiency of the gas-filled lamp over the vacuum, in the sizes usually used for poultry lighting purposes, while the latter is cheaper. As the type of filament employed in the vacuum pattern lamp is more suitable for reflection, this type of lamp is to be preferred. It should be frosted at the bottom end, as this slightly improves the distribution.

A practical recommendation for most poultry laying houses is a 40-watt vacuum lamp placed in an extensive pattern reflector. The height of this lamp to be six feet above the ground and placed ten feet away from the next lamp. Each lamp to be placed in a central position of each bay of the laying houses.

The following example illustrates how the tables can be used to obtain more precise data. Suppose a poultry house 14 ft. wide by 40 ft. long is to be lighted. The first step is to determine the area of the floor :—

$$14 \times 40 = 560 \text{ sq. ft.}$$

Referring to Table XXVI. the value of x when the floor area is 560 ft. and a dispersive type reflector is used = 0.52. Assum-

ing the voltage of supply to be 110 volts and 40-watt vacuum lamps are to be used, the number of lumens (from Table XXVII.) =370. Now with these facts the number of light points required can be determined :—

$$\frac{560 \times 1.5}{370 \times .52} = 4 \text{ light points in a house of this size.}$$

Fig. 119.—Electric light in the poultry house at Greater Felcourt. (Note the Vitreous enamelled deep bowl type of reflector.

Determining the position of these lamps is comparatively simple. What has to be borne in mind is that as far as possible there should be an equal intensity of light over the feeding space. With the example used above, it would mean that the first lamp should be placed 5 ft. from the end of the house and

the remaining lamps spaced 10 ft. apart. It should also be noted that as the most important part of the floor is the scratching and feeding area and the least important is under the perches and nesting boxes, one half the width of the space covered by the perches and the boxes should be deducted when determining the centre point for fixing the light. A piece of flat board should be hung from the ceiling, so as to control the light on the perches. These should only just come within the bright light.

Control of Lights.

The method of controlling the lights is an important one. When the work is done by means of ordinary hand switches, it entails a considerable amount of inconvenience and if done by a worker, the cost is, of necessity high, owing to the early and late hours at which the lights must be attended to. Further, the regularity, which is an all important matter in the treatment of birds, should not be dependent on the time keeping of any workman. Many birds fall into an early moult if subjected to irregular hours of lighting. However, this need not cause any worry, as there are a number of different methods in use for overcoming the difficulty. They range from cheap alarum clocks, improvised to suit the requirements, which require winding and setting every day, to the most elaborate automatic, self-winding electric time switches, with astronomical attachments, to enable them to follow the varying times of sunrise and sunset.

Before selecting an automatic clock, the programme of light must be decided upon. This will depend partly upon the poultry farmer's convenience and arrangement ; partly on the breed of the birds : also partly on local circumstances, such as the prevalence or otherwise of rats and the charges for electricity (i.e., there may be a higher charge for evening lighting).

The methods in use may be classified as follows :—

(a) evening light from sunset.
(b) morning lighting to sunrise.
(c) a combination of the above.
(d) the late evening feed of one to two hours (usually between 8 and 10 p.m.) often referred to as the "evening lunch."
(e) the combination of the late evening feed with morning lighting.

TABLE XXVIII.

Periods during which light is required when the morning or evening system is adopted :—

From		To		Morning Lighting Lights turned on hours before dawn	Evening Lighting Lights turned off hours after dusk
October	1	October	15	1	1
October	15	October	31	$1\frac{1}{4}$	$1\frac{1}{4}$
October	31	November	15	$1\frac{1}{2}$	$1\frac{1}{2}$
November	15	November	30	2	2
December	1	December	15	$2\frac{1}{2}$	$2\frac{1}{2}$
December	15	December	30	3	3
January	15	January	30	3	3
January	30	February	14	$2\frac{1}{2}$	$2\frac{1}{2}$
February	14	February	28	2	2
March	1	March	15	$1\frac{1}{2}$	$1\frac{1}{2}$
March	15	March	30	1	1

TABLE XXIX.

Periods during which electric light is required in the South of England on the basis of providing ten hours' sleep for the birds, viz., 8.0 p.m. to 6.0 a.m., when the morning and evening lighting system is carried out :—

Length of night	From		To		Average time of sunrise a.m.	Average time of sunset p.m.	No. of hours of light required per day
12 hours	Oct.	1	Oct.	15	6.0	6.0	2
$13\frac{1}{2}$,,	Oct.	15	Nov.	1	6.30	5.0	$3\frac{1}{2}$
15 ,,	Nov.	1	Dec.	1	7.30	4.30	5
16 ,,	Dec.	1	Jan.	15	8.0	4.0	6
16 ,,	Jan.	15	Feb.	15	8.15	4.15	6
$14\frac{1}{2}$,,	Feb.	15	Mar.	1	7.30	5.0	$4\frac{1}{2}$
$13\frac{3}{4}$,,	Mar.	1	Mar.	15	7.0	5.15	$3\frac{3}{4}$
$12\frac{1}{2}$,,	Mar.	15	Apr.	1	6.30	6.0	$2\frac{1}{2}$

In all cases, experience has proved that it is better to switch on a dim light in hours of darkness, before turning the light full on, and also to dim the lights before switching off (so as to allow the birds time to get on their perches).

The author employs a clock which winds itself electrically (Fig. 120); by means of an astronomical attachment, it automatically follows the later or earlier setting of the sun and then switches on. At 8 p.m. it switches in a dimmer for a quarter

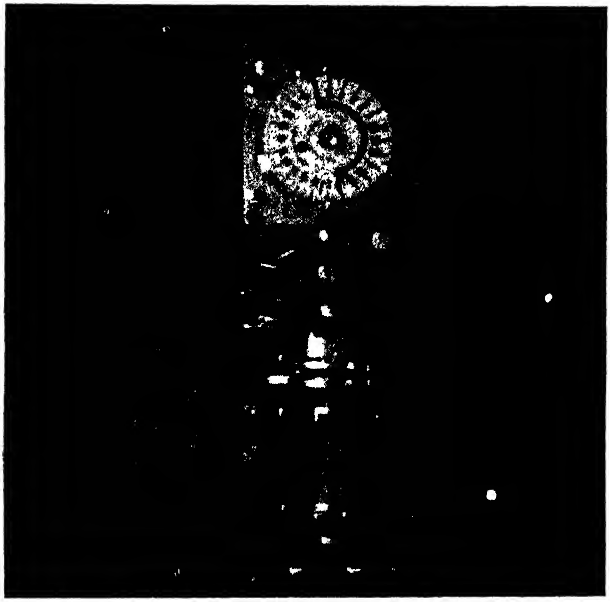


Fig. 120.—An electrically operated clock at Greater Felcourt Poultry Farm. It does everything but talk, it winds itself, turns on and off when required, dims when needed (to imitate the setting or rising sun). Follows the changing time of rising or setting of the sun.

of an hour and then cuts off the light altogether. At 6 a.m., having given the birds ten hours rest it switches on a dim light for a quarter of an hour and full light at 6.15 a.m. At sunrise the automatic astronomical feature again follows the sunrise time and switches off. It is very nice to have such complete control, and it is well worth while with a large number of birds.

However, with smaller flocks, a less elaborate clock device will suffice. In fact, for morning and evening lighting, coupled with automatic dimming, the author has employed two simple automatic clock switches to attain the result of a more comprehensive and expensive single unit.

Many ingenious poultrymen have connected an ordinary alarum clock with a tumbler switch for turning on the lights, while others use two clocks, one for switching on and the other for switching off. Where these are used care must be taken to see that they are wound and set every day. New clocks of this type will probably be required each season. For very large poultry farms the more expensive time switches are the most satisfactory arrangement, because if the cost is averaged over the number of birds generally kept, it will be found to be less than half the price of an egg per bird during the winter months.

There are at least four different systems of wiring in use for dimming the lights. The first is known as the variable resistance-unit system and consists of a variable resistance unit in series with an ordinary circuit, as shown in Fig. 121, which when moved over from A to B gradually dims the light, thereby giving an artificial dusk. After a few minutes the light is turned out by means of a switch.

This method in its usual form has one great disadvantage, and that is that once the resistance has been constructed for a certain number of lights, any re-arrangement of lights calls for a change in the resistance unit. However, tappings can be provided at one end of the coil for extra resistance in anticipation of extensions.

The second system (Fig. 122) is practically the same as the first, except that a fixed resistance is employed, which is short-circuited when the lights are required to be full on. Here again tappings should be provided to allow for future extensions of the lights.

The third way (Fig. 123) is the series-parallel system. This consists of a single series-parallel switch and three wires running the length of the house. The lamps are connected to the first and second, and second and third wire alternately as shown

in diagram. In this way it becomes possible to dim the lights in two stages, as, by the aid of the switch, the two banks of lamps may be put either in series or in parallel. The first position of the switch turns on the two banks in series, causing the light to become so dim that the birds return to their perches, and the last position turns out the light completely.

A fourth method, known as the two-circuit system (Fig. 124), is sometimes used and consists of three wires running the length of the house, which provide the two circuits. Across the one circuit, lamps of about 40-watts are fitted, while across the

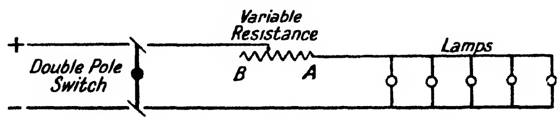


Fig. 121.—Variable Resistance System.

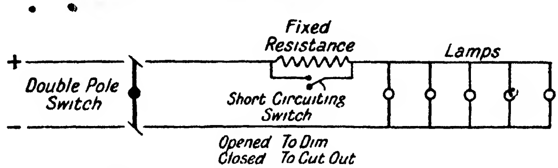


Fig. 122.—Fixed Resistance System.

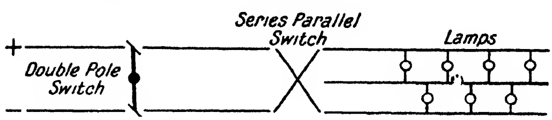


Fig. 123.—Series parallel System.

other, lamps of about 15-watts are arranged. During feeding time, only the 40-watt lamps are turned on. When the dim light is required the 15-watt lamps are turned on and the 40-watt lamps are switched off. These small lamps are left on until all the birds have returned to their perches and are then switched off.

Automatic switches may be used on all these systems of dimming.

Still another way of controlling the lights is where an automatic electric lighting set is employed for laying-house lighting only. The time switch controls the hours of lighting, and the generating set automatically shuts down when the switch

turns off the light, and starts automatically in the morning when the lights are switched on.

Where the supply is alternating current a choke-transformer may be employed, as still another method to those outlined above.

While gradual dimming is still carried out on a number of farms, the author suggests that it might well be dispensed with as the advantages gained do not justify the expense on the gradual dimming arrangements.

One poultry farm in England already uses 45 kilowatts of electric energy for lighting and this is shortly to be doubled,

Wiring of Poultry Houses.

There are in use four main methods of fixing wires (1) by threading them into enamelled steel tubes, (2) by placing them in wood casing, (3) by fastening them at intervals with

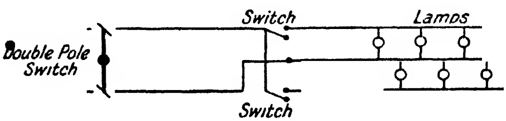


Fig. 124.—Two-circuit System.

clips or cleats, and (4) by use of bare overhead distributors over the houses, with insulated leads into the houses at each lighting point. While all the methods have their advantages under certain conditions, there is no doubt that the third is by far the cheapest and best for poultry house lighting and for this reason reference will only be made to this method There are two general classes of cable used with this method. (1) ordinary vulcanised rubber cable (V.I.R.), and (2) cable, consisting of copper conductors insulated with pure vulcanised rubber over which either (*a*) a tough rubber compound is placed or (*b*) sheathed with a lead composition, or a metal covering. With the first class the cable is mounted on porcelain cleats or insulators, whereas the second can be clipped on any board or beam. This second class (*a*) has proved itself of great value for poultry work, as the insulation will withstand the action of oil, ammonia, acid and other corrosive influences.

It is waterproof, very flexible and easy to install, and though its initial cost is higher than the ordinary vulcanised cable, it will be found a better investment owing to its low erection cost, longer life and freedom from faults. The size of wire recommended for the internal wiring of poultry houses is twin 3/.029. Poultry house wiring is a simple job that can be tackled by any handy man. In fact, a set of components has recently appeared on the market with that end in view. It is known as the Selfix Outfit. With it, any poultryman can complete an electric installation which will meet the requirements of any fire insurance office and of the local electricity supply undertaking. All the necessary cable and accessories are provided, and no soldering has to be done. With the aid of the instruction book supplied with the outfit, the work becomes a simple one-man task, for any person of average intelligence.

Wiring Fittings.

While any standard accessories may be employed, the most suitable ceiling roses are those of the detachable pattern. For one thing, the main wires need not be cut and for another the wiring of the lamp holder to the ceiling rose can be done on the ground, instead of with aching arms over the head. An alternative is the universal all-composition type of combination ceiling rose. The fuses or safety devices should also be of the porcelain detachable type.

Overhead Distribution:

As poultry houses are usually situated some distance apart, the cheapest and most convenient way is to distribute the electricity by means of overhead wires. Where the voltage is 100 or over, considerable economy can be effected by employing galvanised, steel fencing wire of $\frac{3}{16}$ or $\frac{1}{4}$ inch diameter. This wire can be mounted on old telephone insulators. It should be strained in position in the usual manner adopted for erecting wire fences. Any sort of poles that will keep the wires twelve feet above the ground or six feet above the buildings will serve. The two wires should be kept not less than sixteen inches apart. To the tops of the poles and over the current conveying wires an insulated galvanised steel wire should be attached, to protect

the lines from lightning. On each pole, another galvanised wire should be stapled lengthwise, leaving six inches to project at the top and a couple of feet at the ground end. The bottom of these posts should be tarred.

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CHAPTER XVII.

ELECTRICITY ON THE DAIRY FARM.

Decimal Class. 637E

TABLE XXX.

TABLE OF USES OF ELECTRICITY ON THE DAIRY FARM.

Electric lighting.
Ultra-Violet Light treatment.
Clippers and brush groomers.
Vacuum cleaner groomers.
Branders for marking cattle.
Fans for driving off flies in the cow-house.
Vacuum pumps or exhaust fans for withdrawing flies.
Pumping of water.
Milking machines.
Milk cooling and circulating pumps.
Milk bottle cleaners.
Milk bottle filling and capping machines.
Refrigerators.
Ice breakers.
Milk and cream separators.
Milk clarifiers or centrifuges.
Sterilization of milk by :—
  (a) Electrolytic bath.
  (b) High Tension Discharge.
  (c) Ultra-Violet Rays.
Milk and cream pasteurizers.
Butter churns.
Butter workers.
Butter cutting and printing machines.
Butter tampers.

TABLE XXX (*contd*).

Cheese curd breakers and curd grinders.
Casein grinders.
Milk churn transporters.
Milk churn elevators.
Electric water heaters and food warmers.
Milk shakers.
Centrifugal fat testers.
Heating of incubators for testing bacterial content of milk, etc.

Electric light.

It is the usual experience of electricity supply authorities that as soon as electricity is available in an agricultural district, the first use that is made of it is to light the byres. In many cases these buildings are lighted before the farm house and the reason for this is that it is a profitable investment. The author, on his own farm at East Grinstead, though the light was installed chiefly to avoid fire risk, has found that the installation of electric light in the cow byres has practically stopped the milk loss through accidental spillage and the value of the milk saved is more than the cost of the current used.

An interesting experiment was conducted by the Agricultural Engineering Department of Wisconsin University to determine the difference in time taken to work with oil lamps and electric light. The time taken by a working farm foreman, who was accustomed to work both with electric light and oil lamps, for the feeding of livestock was as follows :—

Operation.	Minutes to carry out operation.	
	Oil Lamp.	Electric Light.
Stabling cows	4	3
Cleaning mangers	9.50	7
Weighing and feeding grain ..	31.75	12
Feeding silage and hay ..	39.25	33
	84.50	55

It will be seen that 29.5 minutes were saved in less than an hour and a half, the percentage being 34.9. While this experiment may have been somewhat crude, it does demonstrate that good lighting means a saving of at least half an hour a day (or say one-third the time usually occupied) in the feeding of livestock.

The use of electric light as the only illuminant, adds greatly to the safety and convenience of work, as in the winter it is necessary to work in the byres, both before sunrise and after sunset. The unsafe oil lamp is both dangerous and unsatisfactory owing to its limited range of light and the ever-present danger of fire. The farmer cannot afford to take any fire risks, owing to the distance of the average farm from the nearest fire station. A farm fire, caused by the upsetting of a paraffin lamp, often means the total loss of stock and buildings

Ultra-Violet Light Treatment.

Experiments in connection with the effect of ultra-violet rays upon the health and growth of farm animals, have been carried on for a number of years and satisfactory results have been obtained. During the last few years, the Rowett Research Institute of Aberdeen University, have conducted a considerable amount of research work in this direction. They found that irradiation exerts its maximum effect on growing animals, when the retention of the minerals is low, owing to badly balanced rations.

It is generally realised that a cow in full milk draws upon the calcium store of her own skeleton, and in the case of a heavy milking cow the effect of the continuous loss may prove serious. The Rowett Institute conducted their experiments with lactating goats and found that by treating these animals with ultra-violet rays, the loss of calcium and phosphorus from the body was decreased and in some cases even converted a loss into a gain. It is suggested that this is brought about by an increase in the absorption of these substances from the intestine. As a result of further experimental work on cows, it is suggested that the prevention of loss of calcium and phosphorous from the body during lactation period would increase the period of maximum

yield and safeguard the health of the milking cow. Fig. 125 shows the Hanovia Quartz Lamp for livestock radiation. For other suitable types of Ultra-Violet Lamps see pp. 319-329.

There can be no doubt that the ultra-violet ray treatment during winter months will prove a practical and profitable procedure. It is already in regular use on race-horses.

Clippers and Groomers.

Clipped cows have a better appearance and are more comfortable than unclipped ones. Clipping machines consist of a

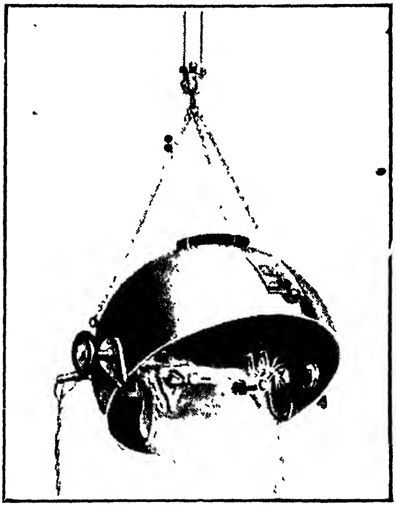

Fig. 125.—Hanovia Quartz Lamp for livestock radiation.

suspended electric motor with an enclosed flexible shaft and a clipping head, in which the cutter moves to and fro on somewhat similar lines to the cutters in hand shears. (Fig. 126). The only manual work required is to push the clipping head against the fall of the hair, when the latter is quickly removed. These clipping heads can be substituted by a grooming brush. The clipping of cows helps to prevent infection of the milk, as manure is not so liable to stick to the rumps of the clipped animals and they are far more easily kept clean. Another method of grooming cows is by the use of a vacuum groomer,

which has been developed in the United States. The principle of this machine is similar to that of the household vacuum cleaner. A receiver is connected by a flexible pipe to a nozzle, of which there are two interchangeable types, the one fitted with a brush and the other with a comb. This is a very sanitary type of

Fig. 126.—Electric clipping machines used on the Author's farm.

groomer as all the dirt is sucked into the receiver, from which it can be removed and burned.

Milking machines.

For many years now, milking machines have been extensively used in America, Canada, Australia and New Zealand,

and also to a small extent are being used on various farms in this country (where they were first initiated), especially in Scotland. In New Zealand alone there are over 16,000 farms employing milking machines and this number is rapidly increasing, while in Sweden there are over 5,000 in use. One maker claims to have sold over 50,000 sets.

The use of the electric motor to drive these milking plants offers another opportunity of increasing the electrical load and also provides the dairy with a neat, compact and silent machine. (Fig. 127). Many a milking machine has gone out of operation, due to trouble with oil engines.

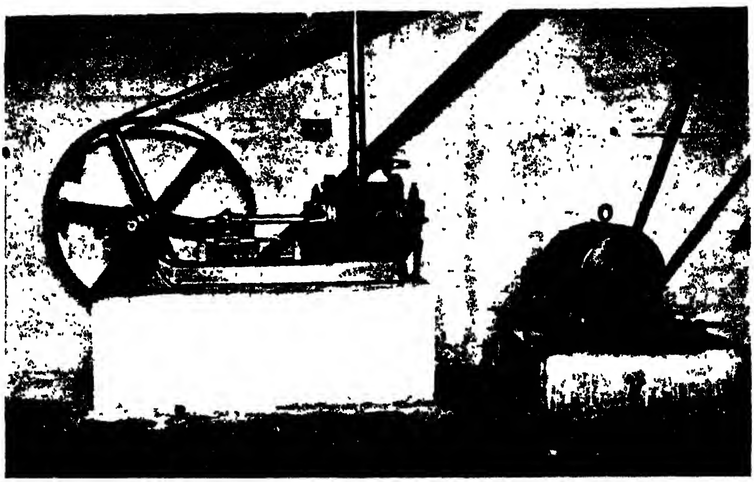

Fig. 127.—Electric motor driving a Vaccar milking machine.

The simplicity of the use of mechanical machines, when equipped with electric motors, was never better demonstrated than with the milking machine, for there is now an electric milker on the market which requires no installation in the byre other than an electric light socket. It is small, compact and light in weight, and can be carried about with ease.

The pump of this small machine is operated through quiet running reduction gears and driven by a $\frac{1}{8}$ h.p. motor. An attachment plug and cord is provided with the machine and

all the operator has to do is to attach the plug and turn on the current. There are on the market about thirty different types of milkers, but they practically all depend on the same principle, viz., an intermittent suction action on the teats of the cow, the suction being relieved at intervals by what is termed a pulsator. This suction is designed to imitate the natural action of the calf. The various machines differ chiefly in the type of teat cup employed, whether the double cup, as in the Gane, Delaval, Vaccar, etc., or the single teat cup as in the Hinman, Lister, and other machines. The first named class gives a slightly different form of massaging effect from the latter.

However, though the question as to which is the better is still a controversial one, there are, nevertheless, very large numbers of machines of both types employed all the world over. The frequency of pulsation is a most important matter and should be about 38 pulsations per minute—about the frequency of the calf when suckling. These pulsations are controlled in three main ways. Two by means of a vacuum pipe for the whole installation, and the other by independent pumps for each cow or pair of cows. These latter pumps are operated either by long sliding shafts or independent electric motors. The pulsations produced by means of the vacuum pipe are regulated (*a*) by means of "pulsators" attached to the milk bucket, and (*b*) by a slide valve forming a part of the main vacuum pump. All the methods have advantages and disadvantages of their own. The objection to the pulsators attached to the buckets is that they are liable to be kicked by a cow, or get slowed up by a cow hair getting on the working parts. The objection to the slide valve control is that sometimes it has to operate through rather a long pipe line.

Teat cups are often so constructed that the vacuum cannot exhaust the air from the cup as quickly or completely when the milk is flowing freely, as when little or no milk is flowing. The cups are usually made of light, tinned metal, with or without indiarubber linings. An important point in the design is to see that they can easily be cleaned.

Electric milkers are a paying proposition when the herd exceeds twelve cows and there is no doubt that with proper

use much time and labour is saved and cleaner milk obtained. (Fig. 128).

A test was recently carried out in California by the California Committee on the Relation of Electricity to Agriculture on the amount of current consumed by these machines. Herds of from 20 to 420 cows giving from 18½ to 29 lbs. of milk per cow per day were studied. It was found that the power required varied from 0.033 kWh to 0.145 kWh per cow per day and the cost of production varied from 0.16d. to 0.5d. per hundred pounds

Fig. 128.—Milking by electricity on the author's farm at Greater Felcourt.

of milk. The average power cost per cow per month was 2½d. It is interesting to note that the cost increased as the herd decreased, the power cost per hundred pounds of milk from the small herd costing three times that for the largest herd. The average time required for milking and the preliminary preparation of each cow was 11.7 minutes per day.

It is sometimes stated that cowmen deliberately interfere with these machines when they are first introduced. But where this is the case it is well to look for the reason before

accepting such a state of affairs as inevitable. It will often be found that care has not been taken to interest the cowman in the new appliance before leaving it to him to operate, with the result that prejudice is aroused and the machine is looked upon merely as a new idea introduced with the object of throwing more of the men out of work.

Under such conditions, faults can be found with any piece of machinery. It cannot be too strongly emphasised that the secret of successfully introducing these machines, is to demonstrate to the men that in this way the task of milking is made easier and the net output of the farm increased; with the result, that instead of employing fewer men, more men can eventually be employed at far more productive and congenial work. A milking machine is just like any other machine and the user must be taught how to use it. Only too many farmers think that all they have got to do is to buy the machine and fix it on to the cows, then are surprised to find that they get all sorts of trouble, as the author did when he first started using these machines.

Bottle Filling and Capping Machines.

As the demand for certified and other clean milk is steadily growing, many farmers have equipped their dairies with a bottle filling and capping machine. There are a number of electrically operated machines on the market to-day which meet the small farmers' requirements, as their capacity is not unduly large. The electric machines of this type are usually driven by a one horse-power electric motor which is direct coupled. Starting up and controlling is a very simple process, the work in most cases being carried out by a girl. The output of such a machine exceeds 1,900 pints per hour and a plant of this nature proves a revenue producing proposition for the farmer, because it reduces labour costs and speeds up production. The depreciation on the plant is comparatively small. Fig. 129 shows an automatic measuring, bottle filling and discing machine, capable of dealing with 3,600 bottles per hour.

Refrigeration.

The temperature of milk when it leaves the cow is somewhere about 98 degrees Fahr. (37 degrees Cent.) and this has

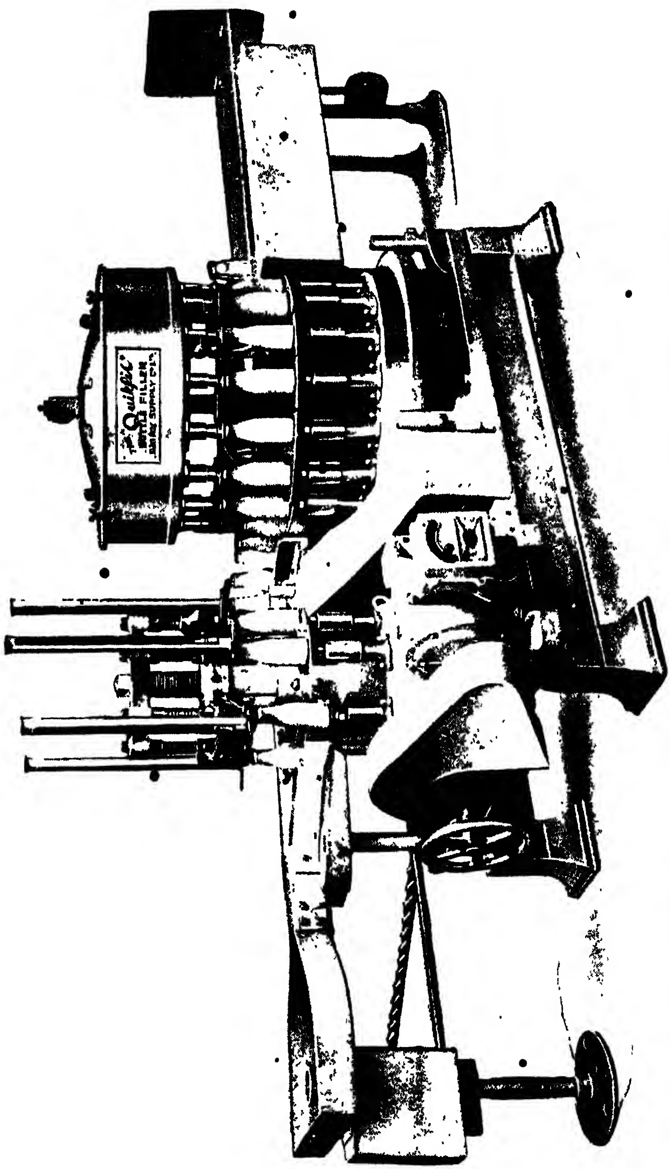

Fig. 129.—An electrically operated automatic measuring, bottle filling and discing machine.

to be reduced to at least 50 degrees Fahr. (10 degrees Cent.) and preferably 40 degrees Fahr. (4.5 degrees Cent.). It is not difficult to obtain a refrigerator of the ordinary water circulation capillary cooler type which will reduce the temperature to round about 55 degrees Fahr. (13 degrees Cent.). However, this is not low enough for the milk to successfully withstand a railway journey, and the conditions of few dairy farmers are such that they can afford to ignore the ill effects of transport

Fig. 130.—Electric milk cooling tank with cover raised.

during the summer months. Frequently, the farmers have churns of milk returned to them sour, in fact, the value of the quantity per season would often go a long way towards paying the interest and depreciation on a small plant. The ordinary type of commercial refrigerating plant is of course out of the question for the average farmer. This means there is a good market for small efficient refrigerating plants, for there are in this country over six million gallons of milk which need cooling daily. The farmer

with an electric power supply can solve his problem in a cheap and efficient manner.

It is possible to install a refrigerating plant, the design of which is perfectly simple and at the same time most ingenious. (Fig. 130). This plant is made up of a concrete tank, with three-inch thick slabs of compressed cork embedded into the bottom and side walls. The tank should be fixed below the level of the ground and be sufficiently deep to allow churns to stand in it with water up to their necks. It must of course be drained. It should be possible to enclose the whole

Fig. 131.— Electric milk cooling tank with cover down.

tank by fitting for it a cover which need be of nothing more elaborate than ordinary match-boarding with slabs of compressed cork, two inches thick, between the layers. (Fig. 131).

The chilling unit of an ordinary domestic electric refrigerating machine is fitted at one end of this tank, below the normal level of the water and in case this should be injured by rough handling of the churns, it is as well to protect it with strong bars of iron. From a commercial air cooled compressor, fixed at the end of the tank, two copper tubes pass through a wooden

plate to the cooling coil. (Fig. 132). The coil, which is of the usual domestic refrigerator type has proved more satisfactory than pipes going round the tank, because it is easier to install and is not so liable to injury. No arrangements need be made for agitating the water, as it is quite sufficient for the dairyman to shake the cans some four or five times during the first hour after their immersion. A standard one-quarter horse-power electric refrigerator will cool about 50 gallons of milk to 40 degrees Fahr. (4.5 degrees Cent.) over night. It does not take more than an hour to bring the milk to a temperature of about 50 degrees Fahr. (10 degrees Cent.) and if the milk is left in the tank overnight the temperature will fall to 40 degrees Fahr. (4.5 degrees Cent.).

Another suggestion for the solution of the dairy refrigerating problem, is the installation of refrigerated capillary coolers.

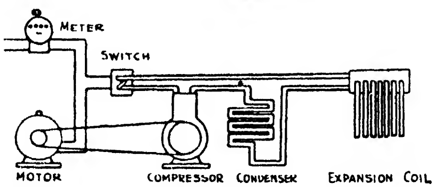

Fig. 132.—Wire and pipe connections.

It is best to arrange these in two sections, the upper part for ordinary water to take away the greater portion of the heat and the lower part to take water nearly at the freezing point from the refrigerator. A slight variation of this method is to use two capillary coolers independently of each other, one for ordinary water and the other for the cooled water. In both cases a special water tank is required in which to place the electric chilling unit, and this tank must be placed above the capillary cooler, and large connecting pipes employed. If these relative positions cannot be managed it will be necessary to have a circulating pump.

Cream Separators.

Low power electric motors now relieve the dairyman of the arduous task of turning a separator. In the average dairy the size of motor required to operate a separator is from one-

eighth to one-sixth of a horse power (Figs. 133 and 134), and the economical way in which it is done is demonstrated on the author's farm, where over 300 gallons of milk are separated by one unit of electricity, and, taking the price at 4d. per unit, the cost is such that no other form of power can possibly compete.

This exceptionally low cost is not the only important consideration, as a separator, if working at its maximum efficiency, i.e., producing the largest amount of cream from a given quantity of milk, requires an absolutely steady drive, and the electric

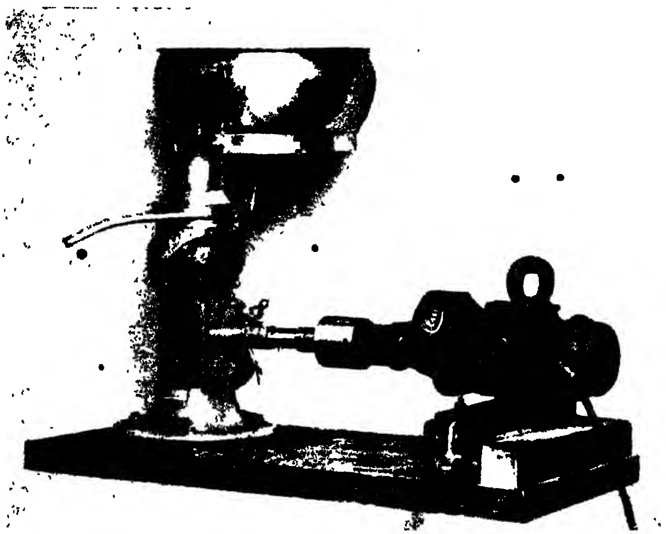

Fig. 133.—Cream separator driven by a small, portable electric motor.

motor is unrivalled where uniform speed is required. The cream separator motor can also be utilised for driving the churn ; manufacturers are paying particular attention to these appliances and many machines embodying these features, are now obtainable. The majority of these machines can be converted to hand drive if necessary.

However, there are a few designed exclusively for electrical drive. In these machines the motor is cast into the separator column or head. The motor armature runs on ball bearings

fitted into grease-tight castings. On the bottom end of the armature spindle a centrifugal clutch is fitted to, and forms part of, the spiral gear wheel, which drives directly on to the spiral spur pinion fitted to the drum spindle. This centrifugal clutch permits of the motor running up to nearly full speed before commencing to drive the drum through the action of the

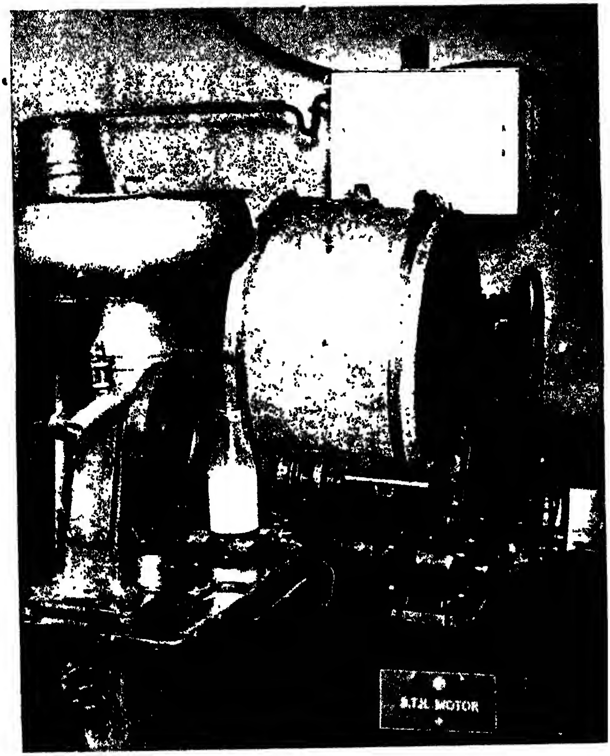

Fig. 134.—Electric motors fitted to a cream separator and to a butter churn.

centrifugal slippers. This provides a smooth, silent drive, free from the friction found in the usual spiral gear. In this way all starting devices are dispensed with as the motor starts on no load.

The popularity of the electrically driven separator, in all dairy farming countries, is becoming more noticeable every

day, in fact, there are over 43,000 electrically-driven separating machines in use in New Zealand to-day.

Milk clarifiers.

Electrically driven milk clarifiers or dirt removers can now be obtained from a number of manufacturers of dairy utensils. (Fig. 135). The centrifugal milk clarifier is a great aid in producing cleaner milk. It removes the solid and semi-solid im-

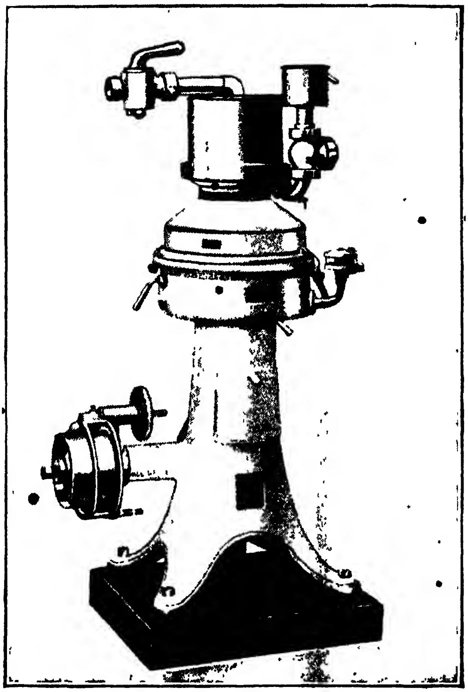

Fig. 135.—Milk clarifier.

purities from the milk by centrifugal force. The milk passes into the machine through a faucet and then into a feed cup, where the flow is regulated according to the capacity of the machine. The milk passes down to the bottom of the bowl through a regulating tube, and afterwards rises up through discs, where it becomes clarified. It then passes out through an

opening at the top of the bowl, from whence it flows through a regulator and is discharged from the machine.

Gerber Milk Centrifuge.

These machines are to be found in many large dairies and are also used by public authorities for testing the percentage of fat in milk. The practice of using them is now becoming universal as dairymen are realising that a tester is not only a protection from prosecution but also enables them to obtain reliable information for use as a guide to the scientific feeding of the herd. (Fig. 136).

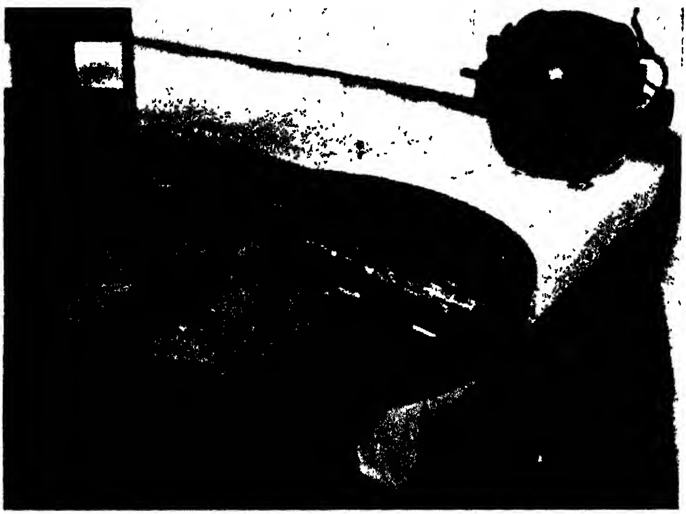

Fig. 136.—Electrically driven Gerber milk Centrifuge.

Sterilization of Milk.

The use of electricity as a means of sterilizing milk has attracted a good deal of attention, because it is so susceptible to precise and accurate control. Experiments, conducted at the Liverpool University, showed that milk could be sterilized electrically without detriment to its nutritive value, and it was also found that when electricity was the sterilizing agent it destroyed Bacillus coli with its allies and tubercle bacilli. Experiments have also been carried out to test the effect of rapidly alternating current at high potential, and it

was found that by this means disease producing and milk souring bacteria were practically destroyed in the raw product.

A number of similar experiments were recently carried out in Holland and in Australia and it was found that the most successful method was to subject the milk to short exposures of high tension current. All coli and allied bacilli were destroyed and there was a great decrease in the number of all other bacteria. The milk was not unduly heated and it was possible to sterilize a continuous stream. Other experiments show that

Fig. 137.—An electric motor driving cream separator and churn.

bacteria in milk are stimulated by the passage of low electric currents.

Another method is to expose the milk to ultra-violet rays while passing over a capillary cooler. These rays undoubtedly produce ozone. The author has experimented with the discharge of ozonized air over the surface of the usual capillary cooler. Ozone, of course, has a deleterious action on the milk if it actually passes through it.

It is clear that more should be known about the result that it is desired to attain in the process of partial or complete sterilization of milk. Bacteriologists seem to be of the opinion that it is preferable that the milk should not be quite sterile, while the aims of commercial interests are to obtain milk that will not turn sour too quickly. There is no doubt that a great improvement could be brought about by greater cleanliness in the milking of the cows and then chilling the milk immediately

Fig. 138.—Butter churn driven by a small portable motor with multiple reduction gear.

after milking. This can be accomplished by the employment of a capillary cooler of which the lower portion is cooled by the circulation of brine from an electrically operated refrigerating machine. The modern "holding" system of pasteurisation is now being largely employed in town dairies. This is another new field for the electric motor.

Butter Churns.

Where an electric motor is employed to drive a cream separator, it can also be used to drive a churn. All that is necessary with most cream separators is to fit a longer second speed shaft fitted with a pulley. These shafts and pulleys are easily obtainable from cream separator manufacturers. For driving the churn a belt should be taken from the small pulley on the separator to a large pulley of about eighteen inches diameter, which is mounted on the churn spindle in place of the

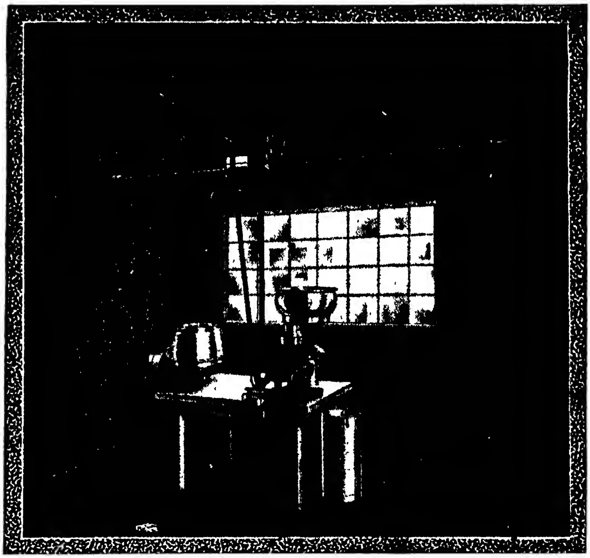

Fig. 139.—Transmission drive of Cream Separator and Butter churn.

crank handle. (Fig. 137). One of the advantages of driving a churn via a separator, is that not only is the separator in use practically every day, but it also provides a counter shaft, since the speed of the average electric motor is too great to connect it directly to a churn. Where the churn in use is a modern one, a one-eighth horse power electric motor is usually quite sufficient. The amount of electricity consumed is very low; in fact, it is hardly more than that required to light a

60 candle-power lamp. Small portable motors with multiple reduction gear can be usefully employed for driving a churn as shown in Fig. 138. Fig. 139 shows an overhead transmission drive of cream separator and butter churn.

Butter cutting and wrapping machines.

It has long been recognised that an efficient machine to cut, mould and wrap butter, would prove a tremendous advantage in the dairy. Until quite recently there had not been a machine capable of performing this work satisfactorily. How-

Fig. 140.—Electrically driven cream separator and electric bottle sealer.

ever, tests have shown that a number of machines now marketed for this purpose fulfil practically every requirement. Such a machine is coupled direct with two electric motors, one for cutting and moulding, having a two horse-power motor, while the one for wrapping needs only a one horse-power motor. The labour saving value of such a machine is enormous, as it can mould and wrap 4,000 ½-lb. or 1-lb. pats or rolls of butter in one hour. From an hygienic point of view, these machines

are very satisfactory, for throughout the process the butter is untouched by hand.

For the cleaning of milk churns, pails, milking machines and other dairy utensils, electric water heaters are very handy. A useful type is the immersion heater, which can be regulated to a certain temperature so that the current is automatically cut off as soon as the water arrives at the required temperature.

Fig. 141.—Small electric motor driving brush for bottle cleaning.

Where Certified or Grade " A " milk is produced an electric bottle sealing device should be used for sealing the caps of milk bottles. These small appliances are simple to operate and carry out the work in a minimum of time. (Fig. 140).

A small electric motor for driving the bottle cleaning brush is also a great time saver. (Fig. 141).

Table XXXI.

SIZES OF MOTORS REQUIRED ON THE DAIRY FARM.

Drive.	Size of Motor in horse power.		
	Usual.	Smallest.	Largest.
Clipper and groomer ..	$\frac{1}{4}$	$\frac{1}{8}$	1
Vacuum cleaner groomer ..	$\frac{1}{4}$	$\frac{1}{8}$	3
Water pump	2	$\frac{1}{8}$	5
Milking machine	2	$\frac{1}{6}$	5
Milk bottle filling machine ..	1	$\frac{1}{2}$	5
Milk bottle capping machine	$\frac{1}{4}$	$\frac{1}{10}$	1
Refrigerating machine ..	3	$\frac{1}{3}$	25
Milk and cream separator ..	$\frac{1}{6}$	$\frac{1}{10}$	$1\frac{1}{2}$
Milk clarifier or centrifuge ..	5	3	10
Butter churn	$\frac{1}{4}$	$\frac{1}{8}$	5
Butter worker	$\frac{1}{1}$	$\frac{1}{8}$	2
Cheese curd breaker ..	$\frac{1}{2}$	$\frac{1}{2}$	1
Milk churn transporter ..	$\frac{1}{2}$	$\frac{1}{2}$	1
Milk churn elevator ..	$\frac{1}{2}$	$\frac{1}{2}$	1
Milk bottle cleaner	$\frac{1}{8}$	$\frac{1}{8}$	1
Centrifugal milk fat tester ..	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{4}$

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CHAPTER XVIII.

BEES.

Decimal Class. 638.1E

A number of interesting experiments have been conducted by the author, to determine the effect of electric light and heat on bees. The desirability of getting the blossoms in an orchard more completely fertilized, especially the early ones, and also of obtaining an increased return of honey, led to the preliminary tests.

All the hives are placed in one building instead of following the usual custom of having them out of doors. Auxiliary openings, or back entrances and alighting boards are provided at the side of the hive which faces inwards. The first important step for getting a strong hive ready for the apple blossom season, is to induce the queen bee to commence laying. This is done by providing food and conditions which will lead her to believe that the warm, settled weather has arrived.

During the late spring, a saucer containing a sugar syrup solution, with which is mixed a little vinegar and salt to simulate brood honey, is placed at the back entrance to the hive. Also another vessel is put down which contains artificial pollen . There are small floats inside the saucers on which the bees rest so that they may not drown while sipping the sugar syrup. The electric lamps in the author's beehouse are covered with porcelain enamelled extensive type reflectors, with a sheet of diffusing glass across the opening. The glass is employed to prevent the bees getting on to the hot lamp and so hurting themselves. A certain number will cling to the glass and others will hang on to them, forming chains. The light must shine on the alighting board, or the bees will not come out. Further, the light must be placed above and near to the vessel containing the syrup. A board or other support must be provided under the

lamp, so as to catch any bees that fall and thus avoid killing them. Any standard heater will serve. The temperature of the house should be about 65 deg. Fahr. (18 deg. Cent.). (Fig. 142).

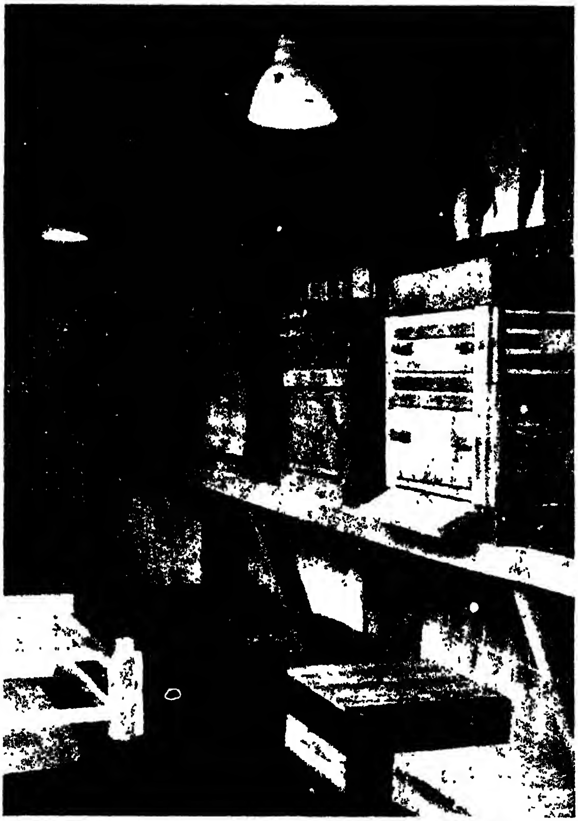

Fig. 142.—Electric light and electric heating of the bee house at Greater Felcourt.

When the hive learns of the food and warmth outside, it awakens to activity, the bees commence to leave the hive to collect honey and the queen begins to lay. In this way, thousands of bees are gathering honey from the apple blossom long

before other bees begin to think of venturing out. It might be added that apple blossom honey is preferred by epicures and is lighter in colour than heather honey. Any bee keeper who takes the little extra trouble involved, will find that he is amply repaid, both by an increased stock of honey, about 17 lbs. per hive per annum, and an improved return of fruit from the orchard. After all, the artificial method simply reproduces natural conditions that occur about once in five years in such a climate as that of Great Britain. Even when the electric lighting

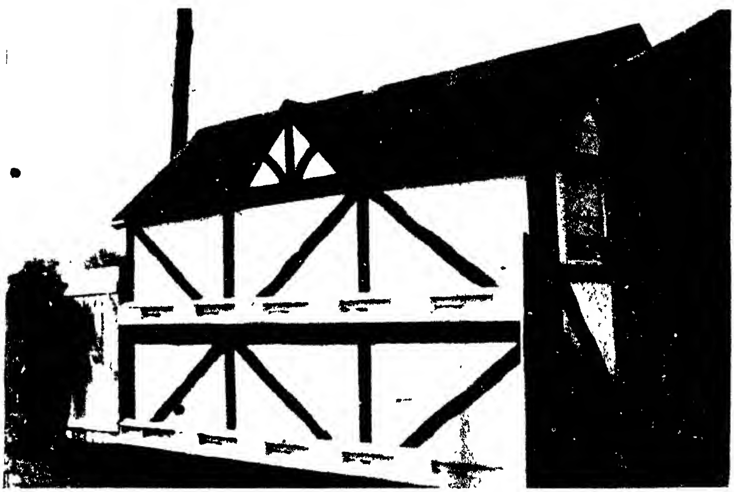

Fig. 143.—An electrified apiary or bee house.

and heating of the beehouse is not carried out, it will be found a great advantage to house the bees in a building during the winter as they are kept warm and do not consume so much of their stored honey for heat producing purposes. (Fig. 143). Mr. E. B. Wedmore has suggested the placing of electric heaters, which would be of about one watt capacity only, in the centre of the hive. In this way, as warmth would be supplied artificially, the bees would not need to consume

their stored honey, to produce the required heat. Considerably more stored honey would thus be rendered available.

At Rothampstead Experimental Station, careful records have been compiled of the interior temperatures of beehives throughout the changing seasons. These temperatures were measured by means of sensitive electric resistance thermometers and hence data is available to estimate the number of watts required if it were decided to supply electric heating.

Experiments to determine the effect of treating bees with ultra violet rays have been conducted in Germany by Stitz & Beyer. They found that irradiated colonies showed increased metabolism and increased comb building. The development of the brood was also hastened. Quartz mercury-vapour lamps, at one metre distance, were used. Irradiation for from five to nine minutes gave increased cell building and fifteen minutes' treatment hastened development.

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CHAPTER XIX.

APPLICATIONS OF ELECTRICITY IN THE HOMESTEAD.

Decimal Class. **640E**

TABLE XXXII.

USES OF ELECTRICITY IN THE HOMESTEAD.
Bacon slicer.
Bed warmer.
Bell.
Boiling ring.
Boot cleaner.
Chafing dish.
Clothes drying cabinet.
Coffee percolator.
Cooker.
Cupboard heater.
Curling iron.
Dish washer.
Drink mixer.
Egg whisk.
Fan.
Flash lamp.
Floor polisher.
Foot warmer.
Griller.
Hair dryer.
Hair waver.
Heaters.

TABLE XXXII (*contd.*)

USES OF ELECTRICITY IN THE HOMESTEAD (*contd.*)

Iron.
Kitchen unit.
Lighting.
Night lights.
Pipe lighter.
Polishing buffs.
Potato pealer.
Radiators.
Refrigerator.
Sewing machines.
Shaving mug.
Tea Kettle.
Tea pots.
Thermostat.
Toaster.
Towel Rail.
Ultra-Violet Ray apparatus.
Urn.
Vacuum cleaner.
Vegetable steamer.
Vibro massage apparatus.
Waffles.
Warming plates.
Washing machine.
Water Heaters (cistern, geyser, immersion and tap).
Wringer for clothes.

The Domestic Load.

From the point of view of the public supply engineer, the farmhouse load is going to make all the difference between profit and loss on a rural line. This has already been discovered in South Wales, where the successful operation of electric washing machines in farmhouse kitchens has been the fore-runner of the installation of electric light and power in the dairy, etc. Similar experience is reported from the United States.

Recent Progress.

When labour is cheap and plentiful, science stands still. In the Feudal ages it would be impossible to conceive the use of such a word as "labour saving" or even "labour aiding" for the simple reason that labour was not a commodity considered worth saving or aiding. In these days of servant problems and shortages, it is hard to grasp the mentality of those far back ages. To-day, housewives are eager to embrace every opportunity of using electricity as their servant, and the past fifteen months have been marked by a series of phenomenal efforts all over the World, and in Great Britain in particular, to extend the field of operations of the supply engineer into the realms of domestic life.

These efforts have included the propaganda work of the British Electrical Development Association and the British Electric Lamp Manufacturers' Association, who, working in conjunction one with the other, have been stage-managing one of the biggest indirect educational advertising efforts ever run in this country. Their work, which aims at the popularisation of electricity for domestic purposes, has been well backed up by the Electricity Supply Authorities in various parts of the country. These latter have installed electric cookers in municipal cookery schools, and have gone a step further by making it possible for electric stoves to be procurable on a hire basis similar to the terms upon which gas stoves are hired. In addition to this, municipalities interested in building schemes have put up some partial and some all-electric houses (Brighton, Glasgow, Hull, Woolwich, etc.). Further, electricity show rooms belonging to electricity supply authorities are becoming the rule rather than the exception.

It is not the purpose of this book to deal to any extent with the application of electricity in the house. The list of such applications quoted above gives a clear idea of the extent of the field covered. Undoubtedly, the most important general uses to which electricity can be put are cooking, vacuum cleaning and washing.

Electric Cooking.

The electric cooker (Fig. 144) has many good points, chief of these being: (1) No waste heat escapes by a flue; (2) current

is turned off directly heat is finished with: (3) there is less dirt: (4) better regulation of temperature: (5) no danger of fire or explosion; (6) meat cooked in the electric oven does not shrink to the extent that is usual when cooked in a coal or gas oven. The saving on the butcher's bills thus attained is usually equal to the cost of the current consumed for the cooking of the meal; (7) all food cooked has a better flavour and also a better colour or bloom.

Fig. 141.—An electric range in a Farm house in Minnesota.

That electric cookers have long passed the experimental stage, is demonstrated by the very large number in use. One manufacturer claims to have made over 20,000. The writer, last year, went to some pains to attempt to get a census of electric cookers now in use in this country. The situation is complicated by the fact that the life of many of the earlier cookers was all too brief. However, as the result of the figures

be collated, the number may be safely taken as well over 36,700. The "Electrical Times," estimated the number as from forty-five to fifty-five thousand, while the British Electrical Development Association's estimate is 74,000. Anyhow, if the smallest figure were halved it should be a convincing enough proof of the fact that the electric cooker has come to stay.

Details have recently come to hand of the answers to a questionnaire sent out to a number of rural customers in Alabama,

Fig. 145. An electrically equipped laundry on an American farm.

U.S.A. These latter were unanimously of the opinion that electric cooking on the whole was satisfactory because the temperature control was good and safety and cleanliness were more assured than with other types of cooker. The only disadvantage found tabulated, was a point brought up on two replies to the effect that in Winter, the electric cooker did not raise the temperature of the air in the kitchen at all, as did other cookers.

This is, of course, a natural disadvantage of an efficient cooker designed to keep a room cool in summer.

Electric Washing Machines.

On the Continent these are in much more general use than in this country, largely because it is possible to obtain an efficient electrically driven machine for about £10 to £18. Numerically, probably America leads the way. In the first three months of 1925, 197,764 washing machines were purchased in the States, and of these 160,353 were electrically driven. Many a farmer has been induced to install an electric motor in his barns because

Fig. 146.—Operating a typical French washing machine.

his wife wanted a washing machine. The work of a farmer's wife is heavy enough as it is, hence the acquisition of a washing machine is a more than welcome innovation. The steam and heavy labour of the ordinary washing day is eliminated. After all, why rub and scrub when a machine will do it for a few pence per day? (Figs. 145 and 146).

Electric Refrigeration.

Electric refrigeration would appear to have a future in the farmhouse. With the veto on preservatives which the law has

laid down, it is certain that some type of refrigeration is quickly becoming a necessity in all households. Most of the makes of electrically operated refrigerators—from the domestic maintenance point of view—have rather too many joints in their construction. However, one type has the compressor hermetically soldered up inside it, hence for a period of over ten years it needs no attention, except to lubricate two external bearings. Another make has its A.C. motor armature and compressor sealed up. Still another is an entirely welded structure without any moving mechanical parts. Certain of the machines are provided with fan cooled compressors, hence the nuisance and cost of a cold water supply is eliminated. A defect in the case of those refrigerators which have a part revolving in a brine solution is the frothing of the latter. The trouble is, however, mitigated in some designs.

An enterprising London builder has just contracted for 1,200 refrigerators for new houses that he is building south of the Thames. Over 10,000 American made electric refrigerators were sold in England last year, while the works programme for a British factory for 1927 was 15,000. At the same time it is anticipated that a very much larger number than this of foreign make will be imported during the coming year. Cold comfort thus takes unto itself a new meaning, when electric refrigeration is under consideration, for city or country-side, for in addition to the assurance of the hygiene of the household, many little luxuries will be rendered available such as cooled wines, cubelets of ice for drinks, ice-creams, parfaits, mousses, frozen dessert dishes and so on—all due to the availability of an electricity supply. On the farm, it will probably be utilised in conjunction with the dairy, as it will keep eggs, butter, milk, fruit, vegetables, etc., beautifully fresh and sweet. The ideal temperature required is about 40 deg. Fahr. (4.5 deg. Cent.).

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FINIS.

INDEX.

The decimal classification numbers (for explanation see page 3) are given in detail in the Index. They will be found of great assistance to those having libraries and collections of data. Each chapter has also been given a general classification number, so that the list of contents is in itself a main classification and should be used in conjunction with the Index.